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OPERATIONAL AND MANAGEMENT ASPECTS OF PERIPHERAL  
RADIOLOGICAL COUNTERMEASURES

Final Report  
March 1966

Prepared for

OFFICE OF CIVIL DEFENSE  
Department of the Army  
Washington, D.C. 20310

through the

Technical Management Office  
U.S. Naval Radiological Defense Laboratory  
San Francisco, California 94135

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Summary Report  
of  
OPERATIONAL AND MANAGEMENT ASPECTS OF PERIPHERAL  
RADIOLOGICAL COUNTERMEASURES

March 1966

by

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Summary  
URS 646-4

-111-

#### FOREWORD

This report summarizes the information presented in URS 646-4, Operational and Management Aspects of Peripheral Radiological Countermeasures, which is separately bound.

Summary Report  
of  
OPERATIONAL AND MANAGEMENT ASPECTS OF PERIPHERAL  
RADIOLOGICAL COUNTERMEASURES

Nuclear attack which results in radioactive fallout requires protection of personnel, normally in a civil defense fallout shelter, where they must remain until such a time as radiation levels are sufficiently low as to permit emergence, nominally two weeks. However, conditions may arise which disrupt this regime. For example, the fallout shelter may be inadequate (e.g., radiation levels exceed the design level of the shelter), or the shelter may be unsafe and must be abandoned (e.g., the shelter structure is consumed by fire) or it may be necessary or desirable to undertake emergency actions outside the shelter at very early times (e.g., a crew may be sent to a power generating station to protect its equipment). Such unforeseen situations can result in the exposure of personnel to serious or fatal levels of radiation unless the hazards are recognized and appropriate exposure control procedures are implemented. Peripheral radiological countermeasures are a group of exposure control procedures which can be applied at the local level (i.e., at the shelter) with a minimum of training and planning (in contrast, for example, to decontamination, which also reduces the radiation hazard but requires trained crews and special equipment). The peripheral countermeasures considered in this report are:

- Postattack Evacuation - the orderly movement of people from fallout shelters through contaminated zones to lightly contaminated or uncontaminated areas
- Applied Shielding - the improvement of radiation shielding protection by increasing the mass of material between the radiation source(s) and the occupant
- Dose Equalization - the manipulation of groups of people in various radiological environments to distribute the exposure evenly among the individuals in the group (includes group shielding, which utilizes the mutual shielding effects of bodies in close proximity)
- Exposure Scheduling - the budgeting of dose and the scheduling of operations in complex and variable radiological situations

Peripheral countermeasures can be used for exposure control at any time after the arrival of fallout, but are most effective at very early times. Although dose limitation is a primary purpose of all of the peripheral countermeasures, the choice of a particular countermeasure is influenced by both environmental and radiological parameters. In many cases, to limit radiological dose to an acceptable level, several peripheral countermeasures may have to be used simultaneously or consecutively as part of an overall plan of action.

The technical feasibility of peripheral countermeasures has been established previously; this report investigates operational (e.g., the modus operandi for each peripheral countermeasure, information requirements and sources, etc.) and management (e.g., how can the civil defense organization provide the framework necessary for the implementation of peripheral countermeasures) practicality.

It was found that the value of peripheral countermeasures can be maximized by preattack planning which includes: (1) delegating responsibility for conducting peripheral countermeasures to the lowest possible echelon of activity, leaving the EOC free to concentrate on problems involving several shelters or shelter clusters; (2) establishing "activity zones" (which may be similar to or identical with shelter cluster boundaries), within which independent action can be taken without recourse to the EOC; (3) preparing, for each activity zone, a resource inventory of supplies and equipment which may be useful in supporting peripheral countermeasures. It appears that such limited preattack planning on the part of the local civil defense organization can lessen operational and management constraints on the postattack use of peripheral countermeasures. Preattack planning should also include the recognition of potential postattack demands for peripheral countermeasures (through war gaming techniques which suggest informational requirements and sources). Although preattack planning provides the best basis for the postattack implementation of peripheral countermeasures, the absence of such planning does not necessarily negate the postattack implementation of peripheral countermeasures.

Planning aids which can be used for calculating dose (both accumulated dose and equivalent residual dose) for complex radiological situations were

derived for use with decision procedures which related threat and available information to possible action options (i.e., which peripheral countermeasures should be used).

The practicality of the concepts proposed in this report were tested on segments of two communities and the feasibility of preattack planning was demonstrated. Selected examples of the use of peripheral countermeasures are given.

It was concluded that the planning necessary for the use of peripheral countermeasures can be integrated into the present civil defense organization with relatively minor effort, resulting in an appreciable payoff in the post-attack period from the successful implementation of peripheral countermeasures. Since problems related to the planning required and the payoff obtained may change for various attacks and for various communities, it is recommended that further study be given to confirm the findings of this report within a "realistic" framework and that theoretical and/or experimental studies be undertaken to verify some of the basic parameters related to the use and usefulness of peripheral countermeasures.

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## ABSTRACT

The operational constraints and management problems associated with the planning and implementation of peripheral radiological countermeasures have been investigated in this report. The four peripheral countermeasures studied (postattack evacuation, applied shielding, dose equalization - including group shielding - and exposure scheduling) can be useful to the local civil defense organization in providing a significant degree of control over radiation exposure in the early postattack period, and their use may result in a reduction of dose to personnel and/or a decrease in the time till emergence from shelter is possible. Moreover, the flexibility in scheduling made possible by the use of peripheral countermeasures can increase the scope of lifesaving activities and permit earlier initiation of the recovery phase.

Operational constraints, such as when, how and where to act, can be lessened by a limited preattack planning effort on the part of the local civil defense organization. Such planning includes recognition of potential post-attack demands for peripheral countermeasures (through war gaming techniques which test informational and resource requirements) and probable response capabilities (from a preattack inventory of vital resources and supplies). In addition to preattack planning (which is not necessarily essential, but is certainly of great benefit) the implementation of peripheral countermeasures depends on the availability of planning aids and procedures which permit the rapid evaluation of inputs so that decisions can be made as to possible action options. A number of such planning aids and procedures are included in the report.

The major management constraint on the use of peripheral countermeasures concerns the rapidity with which decisions can be reached so that action can be initiated. Response time can best be minimized by delegating authority for local action to the local level, i.e., to the shelter. However, such a division of responsibility is feasible (without sacrificing the coordination function of the EOC) only if the extent of local action, both as to area and duration, is clearly defined in preattack planning.



It was concluded that the degree of preattack planning deemed necessary for peripheral countermeasures can be integrated into the present civil defense organization with relatively minor difficulty, resulting in an appreciable payoff in postattack capabilities. Since problems related to the planning required and the payoff obtained may change for various attack conditions and for various communities it is recommended that further study be made to confirm the findings of this report within a "realistic" framework. It is also recommended that theoretical and/or experimental studies be undertaken to verify some of the basic parameters related to the use and usefulness of peripheral countermeasures.

#### ACKNOWLEDGEMENTS

The author is appreciative of the contributions of Miss Ann Willson of URS, who prepared Appendix E and is responsible for the mathematical computations throughout the report.

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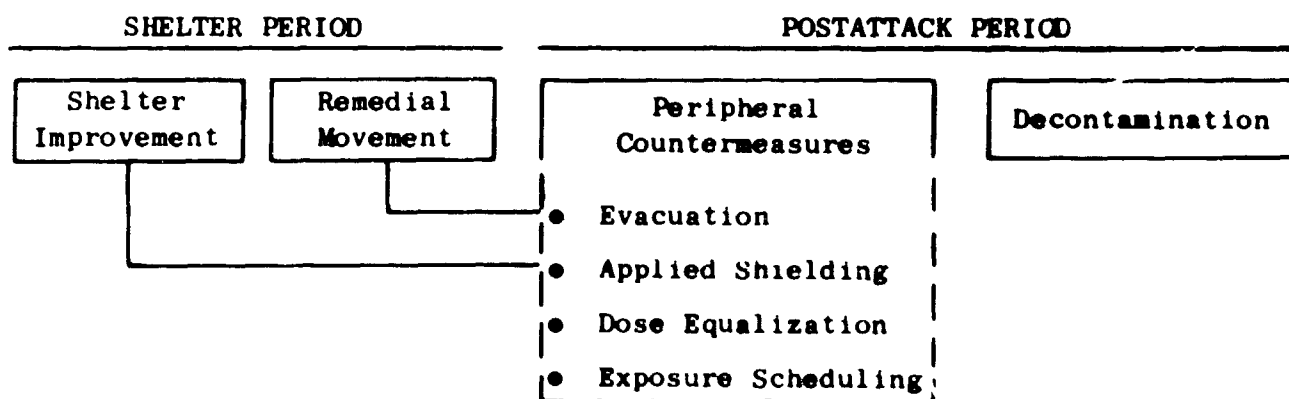
## Section 1

### INTRODUCTION AND OBJECTIVES

Nuclear attack which results in radioactive fallout poses special problems in that persons must retire to fallout shelters until such time as radiation levels are sufficiently low to allow resumption of necessary operations. In the days and weeks following attack – the early postattack period – primary concerns are to vacate the shelters and initiate recovery.

The scheduling of activities during and subsequent to this transition period can be restricted or rendered infeasible by radiological environments which expose personnel to excessive radiation. The operational restraints imposed by allowable dose limits can be reduced in many cases by the use of exposure control techniques. The major exposure control techniques (excluding medical preventative measures) and their primary relationships are shown below:

#### TECHNIQUES



More specifically, exposure control techniques are defined as:

- Shelter Improvement. The improvement of the radiation protection of radiologically inadequate shelters by application of additional shielding (similar in concept to applied shielding) or by removing a portion of the radiation source (limited decontamination), thus reducing the dose rate.

- Remedial Movement. The movement from a radiologically inadequate shelter to a radiologically adequate shelter at such a time that dose will be minimized (similar in concept to evacuation).
- Postattack Evacuation. The orderly movement of people from fallout shelters through contaminated zones to lightly contaminated or uncontaminated zones, staging areas, or living and working areas.
- Applied Shielding. The improvement of radiation shielding protection at lightly protected areas that might be used as staging, living, or work areas.
- Dose Equalization. The manipulation of groups of people in various radiological environments to distribute the exposure evenly among the individuals in the group (includes group shielding).
- Exposure Scheduling. The budgeting of dose and scheduling of operations in complex and variable radiological situations to limit the maximum exposure of group members.
- Decontamination. Removal (or, in some cases, covering) of the source of the radiation by techniques such as firehosing or sweeping, thus reducing the radiation dose rate.

The selection of one radiological countermeasure in preference to another in a given situation is dependent on many parameters, although the prevention of overexposures is the primary criterion. In many cases, to limit radiation dose to an acceptable level, several countermeasures will have to be applied simultaneously or consecutively, as part of an over-all plan of action. Many of the problems involved in employing radiological countermeasures, including decontamination, are related to understanding the modus operandi, to achieving the capability to justify such operations for specific situations, and to planning their implementation.

The purpose of the present study is limited primarily to an investigation of the applicability of peripheral radiological countermeasures<sup>1</sup>

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<sup>1</sup> Peripheral countermeasures which involve the control of internal radiation hazards resulting from ingestion (i.e., breathing, eating, or drinking) or the use of medical or chemical aids to counteract the effects of radiation on the body will not be considered in this report.



and to a determination of the means by which civil defense organizations can use such countermeasures. More specifically, the contractual work statement defines the investigations as follows:

- (1) Investigate possible peripheral radiological countermeasures (not including decontamination) to be initiated in postattack situations.
- (2) Develop models which will allow simple but rapid determination of the effectiveness of the proposed actions.
- (3) Prepare plans and guidelines by which peripheral countermeasures would be implemented and utilized by local governmental authority and by shelter managers.
- (4) Study feasible exposure control countermeasures for both short- and long-term exposures from the time of shelter emergence until orderly transferral of survival functions can be made to the preattack governmental and private institutions.
- (5) Develop these studies into action options and planning guides for the local civil defense authorities to implement under postattack conditions.

As will be detailed subsequently, the technical feasibility of most of the peripheral countermeasures has been demonstrated previously, and conditions in which they are potentially effective have been defined. However, such conclusions are based on the measures being used in idealized situations, in which, for example, planning personnel have all the accurate knowledge and information that they need, resources are readily available, and communications are adequate.

To properly assess the effectiveness of peripheral countermeasures, the objectives were paraphrased to read as follows:

1. Investigate the practicality of peripheral radiological countermeasures (including postattack evacuation, applied shielding, exposure equalization, and exposure scheduling), taking into account the capability of local civil defense organization to plan and execute such measures.
2. Develop planning aids and procedures to allow local civil defense to plan and implement peripheral countermeasures effectively in the postattack period.

## Section 2

### BACKGROUND AND SCOPE

#### BACKGROUND

As previously indicated, prior studies have delineated the technical feasibility of various peripheral countermeasures. A prior investigation at URS (Ref 1) showed that postattack evacuation and applied shielding had a significant payoff in terms of dose and/or time saved, and hence were technically feasible. More specifically, it was concluded that postattack evacuation, if properly planned, would permit earlier emergence from primary fallout shelters, as well as control of the dose received by evacuees. It was also concluded that the use of applied shielding to improve the radiation protection characteristics of lightly constructed structures was both feasible and practical, although in many cases it required more effort than did limited decontamination. Applied shielding was particularly useful for reducing the radiation entering door and window openings of heavily walled structures. It was concluded from this study that decision making and planning procedures were complicated by the many parameters that had to be considered, and that only extensive detailed planning (much in the preattack period) would ensure the successful implementation of peripheral countermeasures in the postattack period.

A study by General Technologies Corporation (Ref. 2) considered the value of control of the movement of groups of people in radiation fields and found that mutual shielding effect, in large groups of people were significant.<sup>1</sup> For example, the effective protection factor (PF) of a shelter could theoretically be raised by a factor of 3.5 or more by the use of group shielding, plus random circulation of personnel within the

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<sup>1</sup> The results and conclusions are based upon the assumption that a point in the body 3 ft above the floor or ground adequately represents the entire body as far as the effects of radiation are concerned.

group. Also, the use of close formations during the movement of large groups over open terrain would reduce the dose received by an individual by a factor of 2 or more. In this study it was also found that the maximum effectiveness was obtained by using a combination of group shielding and limited decontamination.

The investigation of other countermeasures, including remedial movement and shelter improvement, although extending beyond the scope of the present study, is closely related. In some instances, the applications are comparable with peripheral countermeasures. Remedial movement, in which personnel transfer at early times from a refuge (PF less than 40) into radiologically adequate shelters, has been investigated by Hawkins (Ref. 3), who found that maximum payoff was obtained for fallout arrival at early times and for refuges of PF less than 10. The maximum reference radiation intensity for which remedial movement was feasible was found to be 2000 r/hr. Technical Operations, Inc. (Ref. 4) also studied remedial movement and derived an approximation for determining the optimum time of movement. Their study indicated that remedial movement had the best payoff when the protection provided by the secondary shelter was much greater than that in the initial shelter (or refuge).

Shelter improvement, in which the PF of an existing shelter is increased by various expedient methods, is briefly discussed in a number of documents dealing with preattack planning and preparation. A recent report by Research Triangle Institute (Ref. 5) investigates the value of attempting to improve potential shelters in the event that an attack seems imminent. As might be expected, the payoff is found to be greatest for shelters with a low PF. Shelter improvement after attack, using applied shielding and/or limited decontamination, has been discussed in Ref. 1; payoff is greatest when the shelter improvement is undertaken within the first 24 hr after attack.

A number of studies have shown decontamination to be of value in

accelerating postattack recovery. However, the possible value of limited decontamination around shelter buildings has received little study, possibly because decontamination, in order to affect shelter dose to an appreciable extent, must be instituted at very early times.<sup>2</sup> Research Triangle Institute (Ref. 6) has investigated the effect of limited decontamination on nine selected NFSS<sup>3</sup> shelters. From their analysis it was predicted that with 100% effective decontamination of selected areas around the shelter structure, the dose rate (but not necessarily the dose) received within the shelters would be decreased by factors ranging from 3 to 1,000. In another study (Ref. 1) the value of limited decontamination was found to be less significant; in only one case was the dose rate decreased by more than a factor of 3.

The usefulness of limited decontamination in reducing the entry time, i.e., the time at which recovery operations could begin, has also been investigated. Hawkins (Ref. 7) found for industrial complexes that limited decontamination could result in time savings of 26 to 29-1/2 days, "not insignificant when it represents time made available for productive effort." Similar results were found for decontamination of oil refineries (Ref. 8), where time saved varied from 3 days for a reference intensity of 30 r/hr to 65 days for a reference intensity of 10,000 r/hr.

Peripheral countermeasures are exposure control procedures which would normally be implemented because of a radiation threat. However, other threats, such as an advancing fire front or flooding of a shelter, might force personnel into a radiological environment, thereby generating a requirement for peripheral countermeasures. Table 1 lists possible threats and hazards to personnel in shelters and possible remedial action, and indicates the potential radiation threat associated with the action.

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<sup>2</sup> Roof washdown systems have been proposed as a means of performing a limited decontamination function at very early times without exposing personnel to high-intensity radiation fields.

<sup>3</sup> National Fallout Shelter Survey

Table 1  
EMERGENCY OPERATIONAL SITUATIONS AND REMEDIAL ACTIONS

Threat or Hazard	Possible Remedial Action	Potential Radiation Threat
Advancing fire front or shelter structure ignited	<ol style="list-style-type: none"> <li>1. Button up and wait</li> <li>2. Move to safer structure</li> <li>3. Evacuate fire area</li> </ol>	<p>No</p> <p>Possible</p> <p>Yes</p>
Blast damage weakening structure	<ol style="list-style-type: none"> <li>1. Shore up and repair</li> <li>2. Move to refuge</li> <li>3. Evacuate</li> </ol>	<p>Possible</p> <p>Yes</p> <p>Yes</p>
Overcrowding and inadequate ventilation	<ol style="list-style-type: none"> <li>1. Rotate personnel within other areas in shelter structure</li> <li>2. Move to refuge or other shelters</li> <li>3. Evacuate</li> </ol>	<p>Possible</p> <p>Yes</p> <p>Yes</p>
Flooding	<ol style="list-style-type: none"> <li>1. Pump and/or divert</li> <li>2. Evacuate</li> </ol>	<p>Possible</p> <p>Yes</p>
Shelter radiologically inadequate	<ol style="list-style-type: none"> <li>1. Use applied shielding</li> <li>2. Equalize dose</li> <li>3. Evacuate</li> <li>4. Do nothing</li> </ol>	<p>Yes</p> <p>Yes</p> <p>Yes</p> <p>Yes</p>

In most instances, if radioactive fallout accompanies the attack, the suggested action could result in exposure to potentially dangerous radiation levels, thereby creating a requirement for peripheral countermeasures. A radiologically inadequate shelter, per se, requires the use of peripheral countermeasures.

The secondary effects, i.e., fire, blast, flooding, etc., in addition to creating a requirement for peripheral countermeasures can also modify these requirements. For example, the presence of debris on roads will increase travel time and hence dose, and may necessitate the use of other peripheral countermeasures to control this additional exposure. Since it is impossible to consider all possible combinations of weapons effects, and since in this report the radiological aspect is the most important, simplifying assumptions as to concomitant blast and/or fire have been made for preattack planning purposes. A limit of 3 psi overpressure<sup>4</sup> is suggested for planning purposes; below this limit fires, if they occur, are assumed to be isolated, blast damage to shelters is assumed to be negligible, and transportation routes are assumed to be open. At or above the 3-psi level, it is assumed that widespread fires are probable, damage to shelters may occur, and transportation routes will generally be impassable. These arbitrary limits would not be applicable for postattack implementation since blast and fire effects would be directly observable.

Even as some nonradiological threats (e.g., fire, flooding, etc.) might create a situation requiring the use of peripheral countermeasures; so might other nonradiological considerations impede the intended use of peripheral countermeasures. Although many such threats can be suggested (e.g., panic, criminal acts, outbreak of disease among the shelter

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<sup>4</sup> Based on data in Ref. 9. For preattack planning it is preferable to estimate the vulnerability of each shelter building to various threats. Since information in this area is limited, URS is currently investigating the problem for OCD (Subtask 1617A).

population, etc.), a more predictable problem is a food and/or water shortage in unstocked shelters or refuges<sup>5</sup> which may be occupied in time of emergency. In such unstocked spaces water, although essential for survival, may not present a serious problem, since NFSS has generally found that trapped water sources within buildings could supply the minimum needs of the occupants. On the other hand, food is unlikely to be found within shelter buildings. Although food is not essential to short-term survival, it is a most desirable resource.<sup>6</sup> Because food shortages might impose a constraint on the use of unstocked shelters or refuges, thereby limiting the scope of peripheral countermeasures (Example 1 in Appendix D lists such a situation), some consideration has been given in the report to possible ways of alleviating long-term food shortages.

The report is presented in seven major sections, in which operational and management aspects of peripheral countermeasures are considered. These seven sections are supplemented by six appendixes, which provide greater detail and additional information. These appendixes, although separated from the text for clarity, are an integral part of the study and will be referred to frequently throughout the text.

Section 1 discusses the objectives of the study and differentiates the various exposure control procedures. Section 2 includes background work, scope of the present study and its limitations, and the approach to the study.

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<sup>5</sup> According to Ref. 10, less than one-half of the shelter spaces currently located are stocked with food and water supplies adequate for 14 days' occupancy.

<sup>6</sup> The generally accepted lower limit for daily food consumption is 2,000 cal per day per person (Ref. 11). Although life may be sustained for some time with lower inputs, morbidity rates, especially in the cramped quarters of a shelter (conducive to cross-infections), may increase (Ref. 12).

The use of peripheral countermeasures, Section 3, includes discussions of the rationale for exposure control, the modus operandi of peripheral countermeasures, and the principal situations in which peripheral countermeasures would be employed. Detailed instructions on planning and implementing peripheral countermeasures are given in Appendix A.

Section 4 considers management aspects of peripheral countermeasures. Included are a series of decision procedures which interrelate operational and management inputs, evaluate these inputs, and provide guidance on action required for successful implementation of peripheral countermeasures. The requirements for preattack planning are presented, the value of such planning is established, and the effort and cost is estimated. Possible modifications in the municipal civil defense organization needed to expedite decision-making processes are considered, and possible ways of incorporating such changes are discussed.

Information requirements and sources of such information for both preattack planning and postattack implementation are considered in Section 5. Also discussed are the requirements for and availability of resources for the support of operations using peripheral countermeasures. The use of a preattack inventory of resources used for direct support (such as refuges, heavy equipment, and shielding materials) and indirect support (primarily food and water) is considered, and a detailed procedure for conducting such an inventory is presented in Appendix F. A test of the validity of the proposed requirements and sources in a pilot study of two communities are presented in Appendix C. This pilot study was also used to verify the usefulness of the decision-making procedures in a field situation.

Section 6 presents planning aids which can be used in calculating both accumulated dose and ERD<sup>7</sup>; Appendix B has additional planning aids

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<sup>7</sup> "Equivalent residual dose", a concept (Ref. 13) which considers biological recovery by the body.



which can be used for calculating dose for a variety of radiological environments and operational conditions. Section 6 also considers the importance of various parameters and the effect of these parameters on dose received. The payoff for peripheral countermeasures in terms of time saved is also discussed.

Section 7 includes conclusions based on the findings of the study and recommendations for future work.

### Section 3

#### THE USE OF PERIPHERAL COUNTERMEASURES

#### REQUIREMENTS FOR EXPOSURE CONTROL

Exposure control limits the dose received for a given operation, or series of operations, to (or below) a value defined as the allowable dose,  $D^*$ , normally chosen so that few, if any, people are incapacitated by radiation effects. The dose accumulated by an individual, which may be received over days, weeks, or months and from various radiological environments, can be considered as being related to three distinct operational environments, namely:

$$\text{Dose} = \text{dose in shelter} + \text{dose while traveling} + \text{dose at secondary site} \quad (1)$$

Each increment of dose is determined by dose rate, time and duration of exposure, rate of radioactive decay, and biological recovery. Ignoring biological recovery for the moment (its importance is discussed in Appendix B), the dose received from a three-stage environment, i.e., occupying a shelter from time of attack to time of emergence, traveling unprotected for some distance, and occupying a secondary site for an indefinite period, can be expressed as:

$$D = \frac{I_0}{P_1} (t_1, t_2) + \frac{I'_0}{P_2} (t_2, t_3) + \frac{I''_0}{P_3} (t_3, t_4) \quad (2)$$

where

$D$  = accumulated dose (r)

$I_0$  = reference intensity (r/hr)

$P$  = PF (protection factor)

$t$  = time after burst (H + hr)

Since calculation of dose by means of Eq. (2) for a three-stage environment, i.e., shelter, travel, and secondary site, can be quite complex, aids and procedures which simplify such calculations have been developed and are presented in Appendix B. However, without delving here into the

intricacies of calculating dose, certain important facts can be delineated about dose calculations and exposure control. First, the number of parameters to be considered in Eq. (2) can be reduced by substituting the observed dose rate corrected to  $H + 1$  hr ( $r_{1,2,3}$ ) for the theoretical equivalent,  $I_0/P$ . This substitution also improves the accuracy of the dose calculation since use of observed dose rate data eliminates certain errors inherent in the "PF" concept. (Greene, in Ref. 14, covers this point in some detail.) A second significant point is that, because of the exponential representation of radioactive decay, i.e.,  $t^{-1.2}$ <sup>†</sup>, dose is most rapidly accumulated at early times after attack. The effect of exponential decay on dose is shown in Table 2 which lists the time period to receive a given fraction of total dose (defined in this case as the dose received from exposure to a uniform fallout field from  $H + 1$  hr to  $H + 1$  month). Thus an exposure duration of 0.48 hr, begun at  $H + 1$  hr, is equivalent to an exposure duration of 0.73 hr begun at  $H + 1.48$  hr, etc. The implication of rapid accumulation of dose at early times is that exposure control countermeasures are of the greatest value when initiated at early times. For example, a countermeasure initiated at  $H + 2.2$  hr and maintained until  $H + 216$  hr will affect 70 percent of the total (1 month) dose, whereas a countermeasure initiated at  $H + 36$  hr and maintained until  $H + 216$  hr will affect only 20 percent of the total dose. A further implication, important when total dose is potentially high, is that an overwhelming dose may be received before exposure control procedures are implemented. For example, if total dose (from  $H + 1$  hr to  $H + 1$  month) is estimated to be 1,000 r, continuous occupancy from  $H + 1$  hr would result in a gross overexposure by  $H + 9.6$  hr, and subsequent action would, at best, be of marginal value.

The above discussion indicates the need for early initiation of exposure control procedures when the dose received in a single environment (in this case, the shelter) is potentially threatening. In more complex situations, where dose may be received in two or three environments [cf. Eq. (1)], the relative importance of the dose in each environment must be considered. If the shelter dose is not an important contributor to the

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<sup>†</sup> Shown in Ref. 1 to be sufficiently accurate for preattack planning.

Table 2  
TIME PERIODS FOR RECEIVING A GIVEN FRACTION OF TOTAL DOSE

<u>Time In</u> (H + hr)	<u>Time Out</u> (H + hr)	<u>Elapsed Time</u> (hr)	<u>Fraction of Total Dose†</u>
1.0	1.47	0.47	0.1
1.47	2.2	.73	0.1
2.2	3.4	1.2	0.1
3.4	5.3	1.9	0.1
5.3	9.6	4.3	0.1
9.6	18	8.4	0.1
18	36	18	0.1
36	82	46	0.1
82	216	124	0.1
124	720	596	0.1
			<hr/> 1.0

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† Total dose is here defined as that received from H + 1 hr to H + 1 month, assuming  $t^{-1.2}$  decay and a uniform radiation field. Values are from Fig. B-6.

total dose, the time of initiation of a countermeasure becomes less important, whereas the effectiveness and duration of the procedure become more important. The interrelationship of these parameters — time of initiation of the countermeasure, duration of use, and effectiveness — to dose is discussed in Appendix B.

#### MODUS OPERANDI OF PERIPHERAL COUNTERMEASURES

The four peripheral countermeasures which have been identified and defined are postattack evacuation, applied shielding, dose equalization, and exposure scheduling. Each of these peripheral countermeasures will be discussed in general terms below; detailed procedures for their use are given in Appendix A.

##### Postattack Evacuation

Postattack evacuation is concerned with the movement of people from shelters, where the radiation level is low, through open terrain, where the radiation level may be very high, to a secondary site (staging, living or working areas), where the radiation level is relatively low or nil. Evacuation planning must consider both radiological and operational aspects, i.e., dose rates in the environments to be encountered, time of movement, mode of travel, routes to be taken, duration of travel, choice of secondary site and its habitability, etc. Evacuation can occur very shortly after attack — probably as a result of some threat or hazard — or later, at the time of initiation of recovery. Because of the many possible variations in evacuation procedures, it is advantageous to establish two general cases: local evacuation and general evacuation. Local evacuation is restricted to movement within the "activity zone"<sup>1</sup> at early times after attack. The decision to

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<sup>1</sup> The activity zone concept is proposed in this study (see Section 4) as a means of controlling the physical limits of responsibility and authority. It is a geographically defined area in which certain resources, alternate shelters, and refuges have been assigned — for use during the early post-attack period — to a shelter or shelter cluster. (A shelter cluster consists of two or more closely grouped shelters. Each shelter has a manager, for administrative purposes; one manager is designated the head shelter manager and supervises areas of joint concern.)

evacuate is made by the head shelter manager (the shelter manager if only one shelter is included in the activity zone), although he may seek guidance and/or support from the EOC if communications are operable. The head shelter manager, with the assistance of his staff, reviews the radiological restrictions and the operational capabilities and decides on the details of the evacuation plan. He uses resources available within the activity zone to implement his evacuation plan. If the evacuation plan entails movement outside the designated activity zone or if it encroaches on some other activity zone, clearance through the EOC is mandatory.

General evacuation, normally carried out under less duress than is local evacuation, is controlled by the EOC, although much of the detailed planning may be done at the shelter level. For example, transportation may be obtained within the activity zone and convoy schedules prepared. Radiation constraints can also be determined at the shelter level by means of radiological inputs (for areas outside the activity zone) supplied by the EOC.

Evacuation, as a peripheral countermeasure, is rarely used by itself; rather, it is used in conjunction with other peripheral countermeasures. For example, evacuation may be impractical because of excessively high radiation levels at the secondary site unless applied shielding is used at the intended living area.

#### Applied Shielding

Applied shielding, discussed at some length in Ref. 1, is a procedure for imposing additional mass between the source of the radiation and the shelter or refuge area in order to decrease the dose rate, and therefore the dose, within the shelter or refuge. Applied shielding may be necessary because the inherent protection of the shelter or refuge is too low or because blast and/or fire damage has modified the shielding characteristics of the shelter building. For relatively minor operations, such as sandbagging windows in a basement shelter, a plan and schedule may not be necessary, but for more extensive applied shielding operations, a schedule should be prepared.

The first step is to estimate the relative contributions of the various (apparent) radiation sources, i.e., roof, walls, floor.<sup>2</sup> On the basis of calculated or measured contributions, shielding materials would be allocated to designated locations in or around the shelter. First consideration is always given to any doors or windows which may be present within the shelter since such openings are normally easily barricaded and such action may provide a substantial decrease in the dose rate within the shelter. The protection afforded by a basement shelter is increased by increasing only the mass of the basement ceiling, i.e., the ground floor. A ground-level or semibasement shelter presents a more complex problem because both wall and overhead mass must be increased. A shelter in the middle stories of a tall building would require an increase of the mass in the walls and the overhead and, possibly, in the floor as well.

Additional mass is best supplied by cheap, dense materials such as dirt (in sandbags), bricks, etc., but may also be supplied by larger volumes of less dense, but possibly more attainable materials, such as paper supplies, desks, movable partitions, etc. This mass may be emplaced selectively (e.g., to reduce radiation penetration through windows or doors) or it may encompass the entire shelter. The mass involved may amount to hundreds of tons so that, whenever possible, mechanized procedure should be used.

At the same time it may be necessary to improve the structural characteristics of the building to support the additional load. Details on cost, effort, and effectiveness of various applied shielding techniques are given in Appendix A.

Applied shielding would normally be emplaced by crews from shelters, rather than from an outside agency, and the radiation exposure of such crews should be planned and controlled. The use of exposure scheduling would ensure that crew members did not receive excessive doses, and dose equalization would ensure that the dose was as evenly distributed as possible among

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<sup>2</sup> A semiempirical evaluation, such as that of Ref. 15, in which a uniform distribution of fallout is assumed, could be used for preattack planning purposes, or a radiological survey, such as that described in Appendix G, could be used for postattack purposes.

the shelter population. Dose to crew members can also be reduced by applying shielding only at partially shielded locations and by starting operations at somewhat later times after attack; both of these measures may, however, be detrimental with respect to the dose received by the shelter occupants.

### Dose Equalization

Dose equalization involves the manipulation of people or groups of people between dissimilar radiological environments in such a manner as to ensure that each individual receives approximately the same long-term dose.<sup>3</sup> The rate of dose accumulation might vary considerably from person to person, but the ultimate dose accumulated should be the same for all individuals. High-exposure tasks, such as reconnaissance, damage assessment, etc., should be rotated among qualified shelter occupants; thus, persons with the lowest dose might be assigned to the current "high-exposure" task.<sup>4</sup> With proper planning and scheduling, the dose to every individual in the shelter would approach the same value over a period of 2 weeks or more.

Ideally, the effectiveness of dose equalization would be monitored by means of dosimeters, worn by each individual, which would be read and recorded regularly. Practically the number of dosimeters available is limited, so that one person wearing a dosimeter may have to serve as the indicator of dose for an entire group. The dosimeters available should be distributed to cover the spectrum of activities involving significant exposure and should preferentially be assigned to personnel such as reconnaissance teams working in variable high-intensity fields.

A special form of dose equalization, also related to applied shielding, is group shielding, i.e., the mutual shielding created by a number of bodies

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<sup>3</sup> It is assumed for purposes of this study that the concept of equalizing exposure is acceptable in the early emergency period, when the primary objective of radiation control is saving lives. Various concepts for attempting to achieve lowest exposures for pregnant women, children, and persons of procreative age have been proposed, but none has been incorporated in OGD policy.

<sup>4</sup> Obviously, this concept should not be belabored unless exposures are high and approaching threshold-of-illness level.



in close proximity in a radiation field. Under the best conditions (i.e., a ground-level shelter, a group of 200 or more standing shoulder to shoulder and circulating continually), the average dose received may be reduced by as much as a factor of 4 below that of a single person in the shelter.<sup>5</sup>

Such a cluster grouping, i.e., shoulder to shoulder and continually circulating (to equalize dose differences on the fringe and the center of the group), would undoubtedly be difficult to maintain over a prolonged period, especially if shelter ventilation were marginal. It is impossible to predict how long this difficult physical posture could be maintained; but in some historical instances, gross overcrowding has been endured for days (Ref. 16). However, the maintenance of a cluster grouping for at least 12 hr (sufficiently long to reduce dose significantly -- see Example 1, Appendix D) seems feasible.

Group shielding is most effective for ground-level shelters, somewhat less effective for upper-story shelters, and of relatively little value in below-grade basement shelters (Appendix A). Since close grouping is most desirable, the physiological tensions may be eased somewhat, without excessive loss of effectiveness, by using a somewhat more generous spacing and/or permitting short rest periods every hour.

Group shielding can also be used effectively by groups walking across contaminated terrain. In this case, a more liberal spacing must be allowed, similar to a close-order drill, while marching. Random circulation of the marchers is desirable but may be difficult to implement.

Another special case of dose equalization is rotation of personnel between shelters of different protective value. Rotation would be proposed only if an appreciable difference, at least 25 percent, existed between the dose rates in the two shelters (or a shelter and a refuge) and only if travel dose were low or negligible. A single rotation, properly timed, is sufficient to assure dose equalization in a 2-week period and is operationally more desirable than is a series of rotations between the two shelters.

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<sup>5</sup> If the 200 occupants are scattered, rather than clustered, the dose reduction does not exceed 1.5. Also, see note 1 in Section 2.

### Exposure Scheduling

Exposure scheduling is concerned with the budgeting of dose and the scheduling of operations in complex and variable radiological situations to limit the exposure of individuals and groups. Exposure scheduling, which involves the time of initiation and duration of an operation or series of operations, is basic to all exposure control techniques but, as used herein, will take on a more restrictive meaning, i.e., scheduling of specific tasks, such as applied shielding or reconnaissance, during the early postattack period. Such tasks may be nonrepetitive (e.g., applied shielding) or regularly scheduled (e.g., an hourly check for fires). Tasks which may have to be performed regularly in a high-radiation field may have to be treated as nonrepetitive, i.e., individuals are allowed on this task only once. Nonrepetitive tasks can often be undertaken within a few hours after attack. Continuing tasks (using the same personnel) cannot be initiated until after the first day (Fig. A-3).

### Situations for the Use of Peripheral Countermeasures

Although peripheral countermeasures are applicable in any postattack environment in which radiation is present, certain well-defined situations which have general implications can be delineated. Four of these situations are briefly described below and are further discussed in Chart 1 in the next section.

#### 1. Shelter Is Radiologically Inadequate

People may be forced to take shelter in whatever space is available, including refuges ( $PF < 40$ ), even though the inherent protection afforded by such space may be inadequate in the face of the radiation threat encountered. In such situations, the safety of the occupants can be assured, or at least markedly improved, by the use of group shielding, for short-term alleviation of the radiation threat, and applied shielding, for long-term dose control. However, such action, to be of value, must be taken promptly, otherwise overwhelming dose may be received by the occupants of the refuge or shelter (as discussed previously under Requirements for Exposure Control).

## 2. Shelter Is Endangered by Internal or External Threats

Forced withdrawal from a shelter or refuge in order to save lives may be necessitated by fire threat, blast damage to the shelter structure, flooding, overcrowding in the shelter with attendant substandard ventilation, etc. The need to move could arise with very little notice and might involve, of necessity, a local decision (i.e., one made by the shelter manager). Even though, in this case, radiation is a secondary threat, it effectively limits the action which may be undertaken. If fallout levels are high, travel time would have to be limited, perhaps to a few minutes, and the range of movement would necessarily be quite small. In such a case, forced withdrawal would be a feasible solution only if alternate shelters were available in the permissible travel range. Further, these alternate spaces would have to be radiologically adequate, or procedures for improving their adequacy (group and applied shielding) would have to be instituted.

If a shelter is endangered but fallout levels are low, the constraint on travel distance could be considerably relaxed. A wider radius of movement would be possible and, in some cases, evacuation to a free zone might be deemed the best solution. As travel distance (and time) increases, the use of peripheral countermeasures to control exposure becomes a more important consideration.

## 3. Protection of Resources or Restoration of Vital Service and Facilities

Often the activity zone will contain warehouses, shopping centers, etc., which represent a potential source of stocks and supplies which should be conserved for future use. Also, the activity zone may encompass key elements of utilities, such as an electrical substation, or vital industries, such as an oil refinery, which should be maintained to minimize damage and, possibly, revitalized to serve the remaining community. The occupation of such facilities at early times (1-7 days) can be facilitated by the use of peripheral countermeasures, including applied shielding (at the work site), exposure scheduling, and dose equalization.

#### 4. Emergence From Shelter Preparatory to the Recovery Phase

Recovery operations would normally be undertaken only after radiation levels had decreased to acceptable levels. Nominally this time is assumed to average 2 weeks but can vary greatly, depending on the radiation levels present, the schedule of work to be performed, etc. Three distinct options for emergence from shelter are listed below:

- Move from the shelter into the immediate surroundings. Local reoccupancy is possible if radiation levels are sufficiently low or if reduction of the radiation levels, either by decontamination or by applied shielding, is undertaken. Extensive blast and/or fire damage would negate this option.
- Evacuate to a staging area at some distance where radiation levels are less and living conditions are more tolerable.
- Evacuate the radiologically contaminated area entirely, moving into a "free zone."

## Section 4

## MANAGEMENT ASPECTS OF PERIPHERAL COUNTERMEASURES

## DECISION PROCEDURES

A series of charts (Charts 1 through 4) for decision procedures have been prepared for use in understanding the relationship between peripheral countermeasures and threat, necessary action, information needs, information sources, and radiological constraints. These decision procedures can also be used as a guide in implementing peripheral countermeasures if the necessary degree of preattack planning, discussed subsequently, has been carried out. These decision procedures cover the relationship of: the situation created by the attack and the necessary action (Chart 1); information needs, information sources, and decision required (Chart 2); threat to personnel, decision required, and radiological constraints (Chart 3); and peripheral countermeasures and radiological constraints (Chart 4). These four charts, although usable independently, are most useful when considered sequentially.

Chart 1 provides a basis for determining what type of action might be required at various times after attack. The initial question which must be considered is the immediate survival of the shelter (or refuge) occupants. If fire, flooding, blast damage, hunger, thirst, etc. threaten the shelter population, forced withdrawal to another shelter at very early times would be indicated. If the threat to the shelter (or refuge) occupants is from excessive radiation, various peripheral countermeasures (e.g., group shielding or applied shielding) could be instituted, again at early times. If these peripheral countermeasures could not, for any reason, be undertaken, or if they were inadequate to counteract the hazard, remedial movement (not included in this study) to a better protected location would be considered. If no immediate threat is present, the possibility of providing support to vital facilities or to protecting important resources, either in the activity zone or elsewhere as designated by the EOC, can be considered. A decision to relocate selected personnel for such a support function would probably be made only after secondary weapon effects (late fallout, fire) had subsided.

Chart 1

## DECISION PROCEDURE FOR EMERGENCE FROM SHELTER

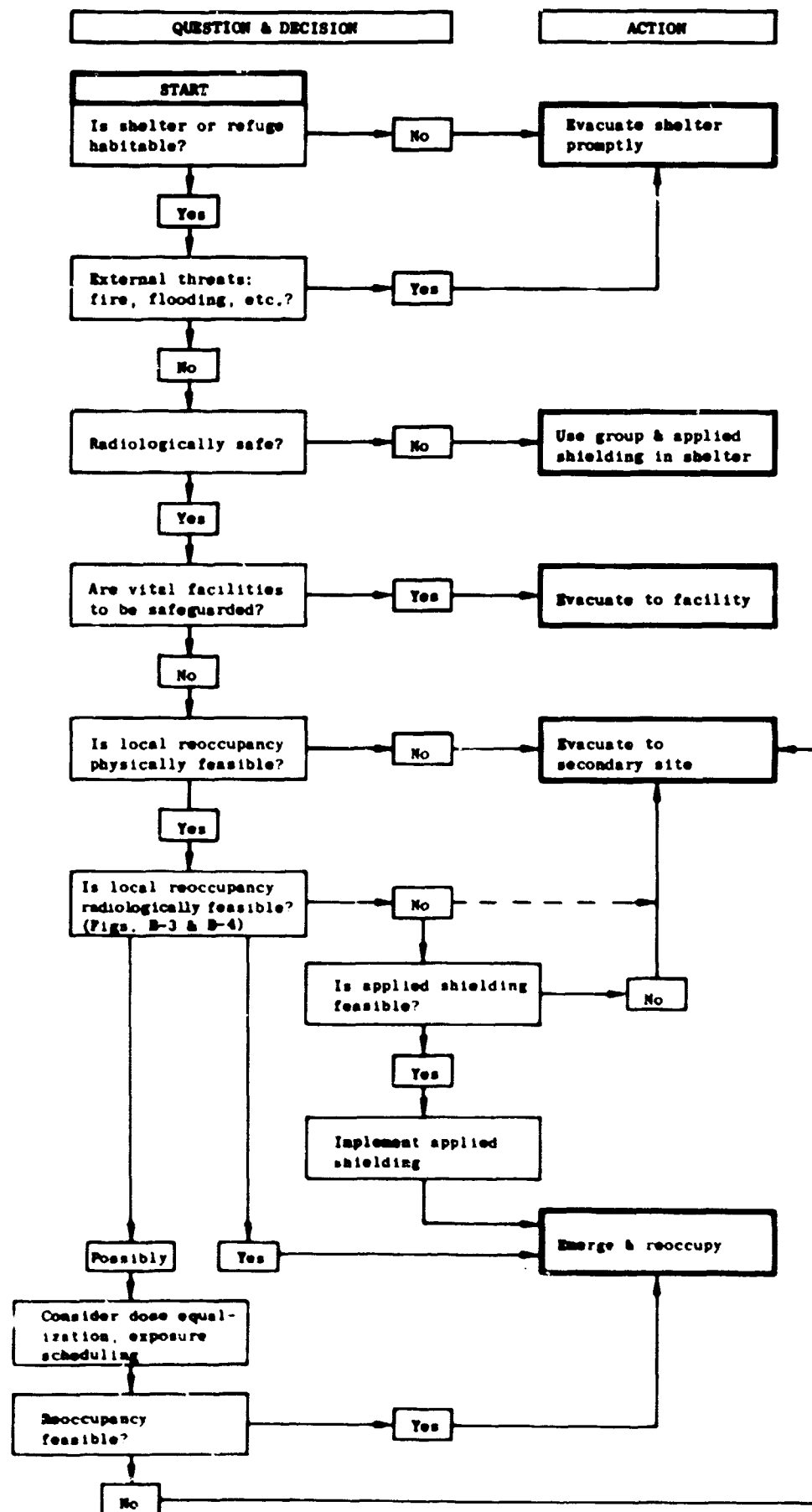
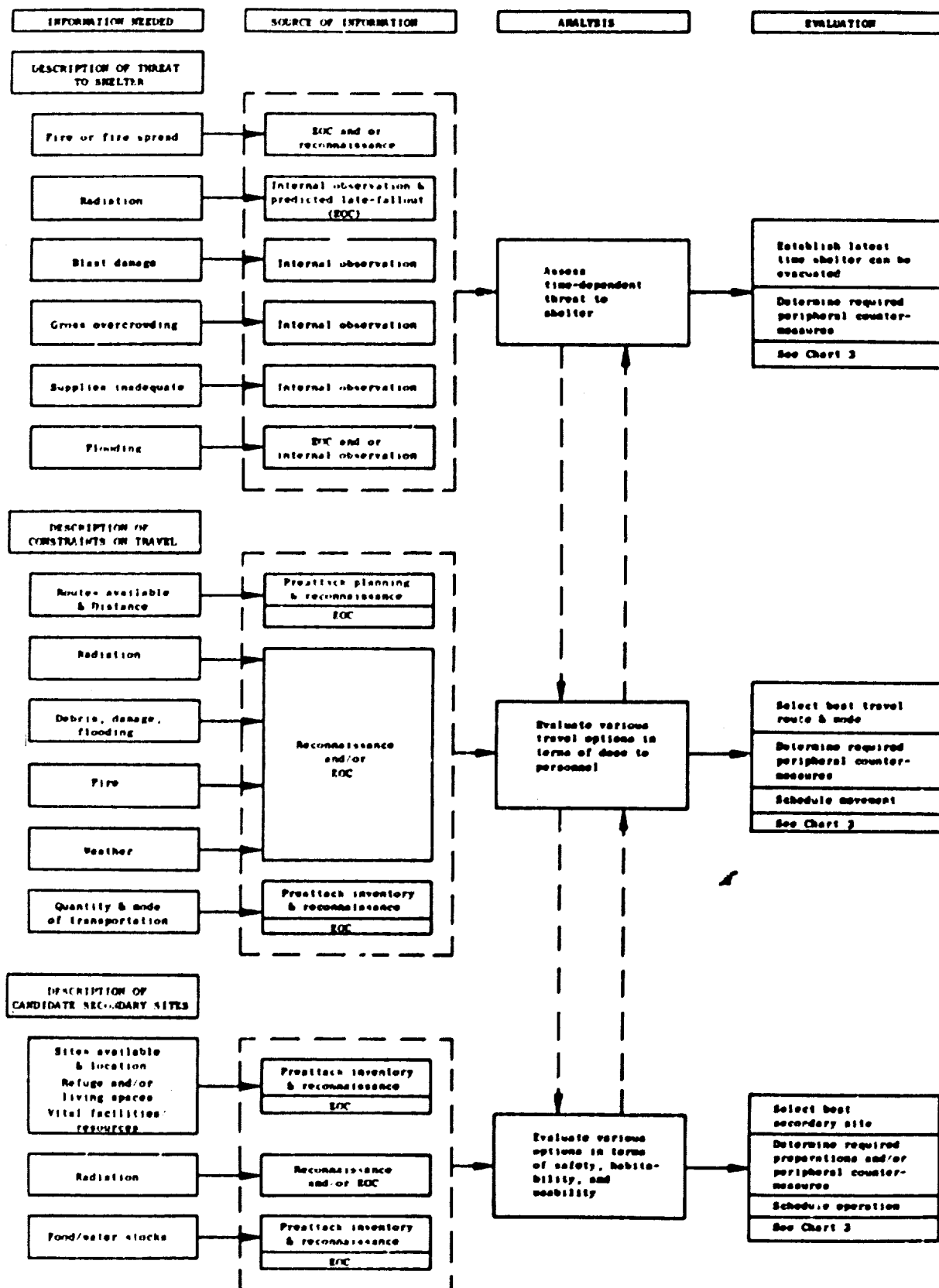


Chart 2  
INFORMATIONAL NEEDS AND SOURCES AND EVALUATION REQUIRED







STEP 1. ESTABLISH OPERATIONAL LIMITS:

- a. Allowable dose ( $D^0$ )<sup>(1)</sup>
- b. Desired go-time ( $t_g$ )
- c. Estimated travel time
- d. Estimated stay time in secondary site<sup>(2)</sup>

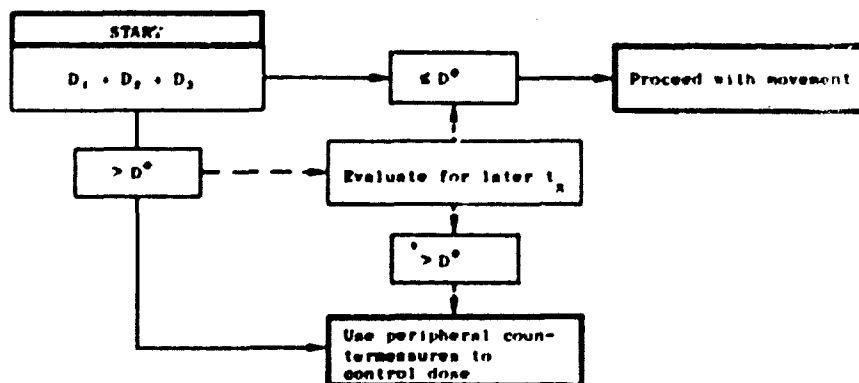
STEP 2. OBTAIN RADIOLOGICAL DATA ON:

- a. Dose rate along travel route
- b. Dose rate at secondary site

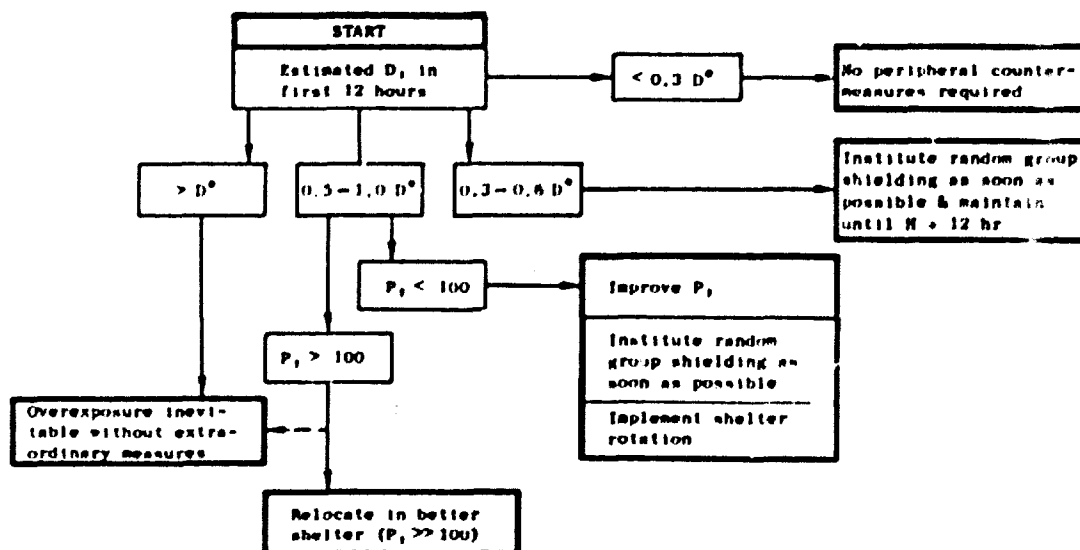
STEP 3. FROM OBSERVED DOSE & DOSE RATES PREDICT:<sup>(2)</sup>

- a. Dose in shelter ( $D_1$ )
- b. Dose in transit ( $D_2$ )
- c. Dose at secondary site ( $D_3$ )

STEP 4. DETERMINE REQUIREMENTS FOR PERIPHERAL COUNTERMEASURES



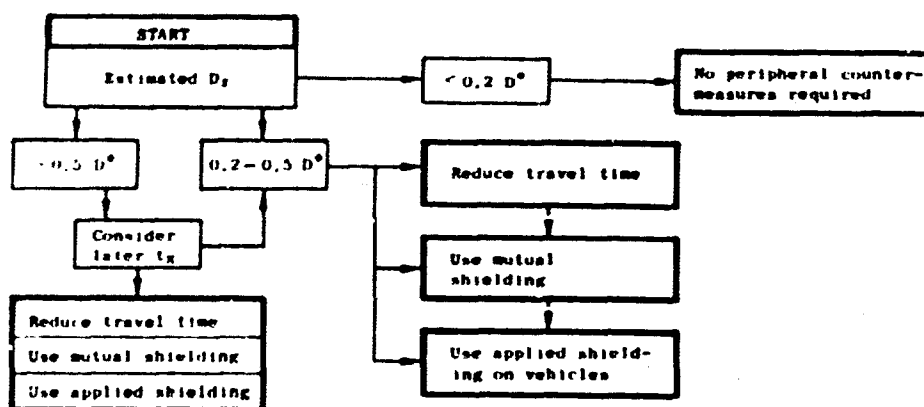
STEP 5a. USE OF PERIPHERAL COUNTERMEASURES IN SHELTER



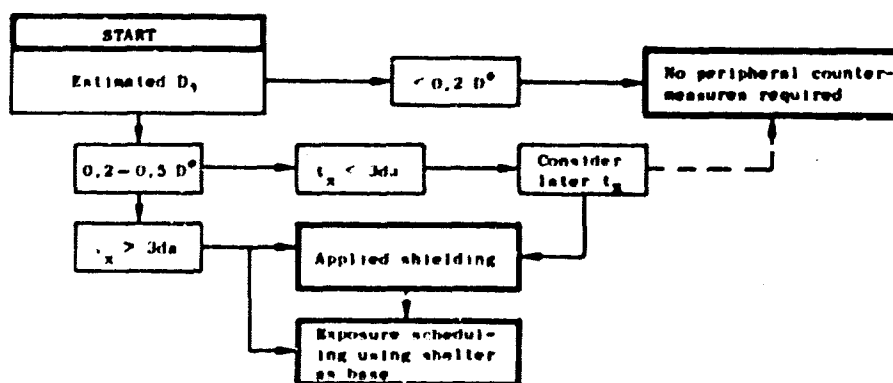
(1) See Table B-1 for conversion of accumulated dose to ERD.

(2) Use Fig. B-8.

## STEP 5b. USE OF PERIPHERAL COUNTERMEASURES IN TRANSIT



## STEP 5c. USE OF PERIPHERAL COUNTERMEASURES AT SECONDARY SITE



## STEP 6. ASSESSMENT OF RESULTS

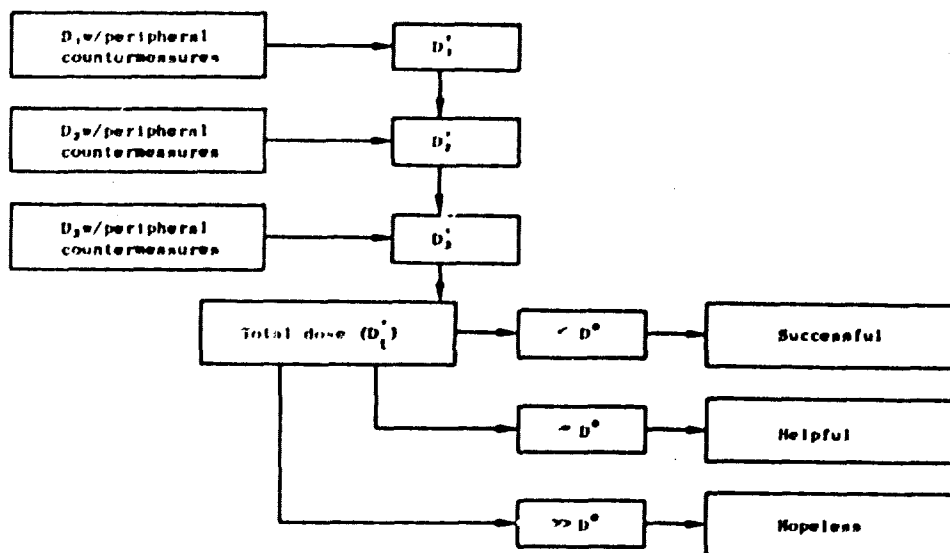


Chart 4

DECISION PROCEDURE FOR USE OF PERIPHERAL COUNTERMEASURES TO CONTROL DOSE IN THREE-STAGE MOVEMENT

**B**

However, initiation of movement at the earliest possible time would be desirable.

As radiation levels drop, the decision must be made as to when, how, and where to emerge from the shelter in preparation for the recovery phase. Emergence at the earliest possible time would probably be desired and would normally occur in the 1- to 3-week time span. In the simplest case, where the activity zone has suffered little or no physical damage and radiation levels are relatively low, local reoccupancy, i.e., movement into available living and working areas in the activity zone, would be practicable. Were local reoccupancy not practical or personnel were needed at other locations, evacuation to more distant areas, where contamination was lower or absent, would be necessary.

Chart 2 lists, as major headings, the information needed for a three-stage environment, the source of such information, and the analysis or assessment of such information needed to arrive at the required decision. The informational needs describe the three environments (i.e., shelter, travel, and secondary site) in terms applicable to peripheral countermeasures. The source of information varies for each environment and with time. In the shelter environment most of the informational input is from internal observations (i.e., within the shelter walls). Internal observations are valid per se but may be modified by reconnaissance of the activity zone or by information supplied by the EOC. For example, flooding might be noted in a basement shelter, and a reconnaissance team might confirm that the street outside was flooding; but the EOC might indicate that the condition was only temporary. However, most information would probably be provided by the shelter itself; this local information should be forwarded as rapidly as possible to the EOC for inclusion in the community-wide damage assessment.

At early times after attack most of the desired information on the travel environment and the secondary site may have to be provided by the shelter itself. Since early emergence would probably be restricted by radiation levels to movement within the activity zone, the shelter can use inventory lists of alternate shelters, refuges and supplies, possible travel routes,

etc., coupled with a reconnaissance of the proposed sites, to obtain the necessary input for implementing necessary action. At later times, the EOC is more likely to provide information for local movement and would certainly provide information and guidance for movement outside the activity zone.

The analysis of the information, discussed in detail in Charts 3 and 4, could be done at the shelter level if suitable manuals and a capable staff were available. The EOC would also have the capability to do such analyses; but because of the probable heavy work load on the EOC, and because much of the necessary information is available only at the shelter level, the function of the EOC might better be restricted to approving and coordinating the plans submitted by the individual shelters.

The decision resulting from the analysis determines what must be done to implement necessary action and the related peripheral countermeasures. The implementation of these decisions is discussed in more detail in Chart 4.

Chart 3 shows for three-stage movement (e.g., forced withdrawal, planned relocation, or evacuation) the relationship of environmental and operational factors (the Information Needed and Decision columns from Chart 1) to radiological constraints, namely the allowable dose. In this decision procedure, environmental factors (e.g., fire spread, mode of transportation, etc.) determine operational requirements (e.g., go-time and travel-time). The operational situation is then assessed with respect to observed or estimated radiological inputs (i.e., dose and/or dose-rate) to provide estimates of the dose in each of the three environments and hence of the total dose. If the total dose is less than the allowable dose, no constraint occurs, and the movement can proceed as planned. If the total dose exceeds the allowable dose somewhat, it may only be necessary to relax the allowable dose criteria by the amount of the overshoot in order to validate the proposed movement. However, if total dose exceeds a realistic allowable dose (e.g., ERD = 200 r) appreciably, peripheral countermeasures, discussed in detail in Chart 4, should be instituted. Another option, in the event that total dose is excessive, is to reevaluate operational criteria and reduce the time spent in high-intensity radiation areas. In case of potentially gross overexposure, all three options

(i.e., increase allowable dose, use peripheral countermeasures, and change operational conditions) may have to be employed.

Detailed decision procedures for the selection and use of peripheral countermeasures for controlling dose are shown in Chart 4. The preliminary steps (1-4), similar to those in Chart 3, establish the need for peripheral countermeasures. The time-phase (i.e., shelter, transit, and secondary site) and the peripheral countermeasures to be applied are shown in steps 5a-c.

Because of the initially high rate of accumulation of dose, peripheral countermeasures have value in the shelter phase (step 5a) only if initiated at very early times. Hence, dose predictions (for convenience, for the first 12 hr after burst) should be initiated soon after fallout starts to arrive and revised regularly as the radiological input becomes more reliable. If  $D_{12}$  (estimated 12-hr dose) is less than  $0.3 D^*$  (the allowable dose), no peripheral countermeasures are required, although their use to reduce dose should be encouraged. If  $D_{12}$  is between  $0.3$  and  $0.6 D^*$ , techniques such as mutual shielding, which reduce the potential dose by a factor of 2 or more, should be instituted. If  $D_{12}$  is between  $0.5$  and  $1.0 D^*$  and the shelter  $PF < 100$ , both group shielding and applied shielding should be used to reduce the potential dose by a factor of 3 or more. This degree of reduction is probably unattainable if the shelter  $PF > 100$ , so that forced withdrawal to a nearby shelter which affords much better protection, i.e., a lower dose rate, becomes necessary. Finally, if  $D_{12} > 1.0 D^*$ , or if a high-protection shelter is not readily available, overexposure is certain to occur unless personnel are evacuated within a few hours by "low dose" techniques (e.g., helicopter and armored vehicles) to uncontaminated areas.

Peripheral countermeasures need not be used if estimated travel dose,  $D_2$  (step 5b), is less than  $0.2 D^*$ . If  $D_2$  is from  $0.2$  to  $0.5$  of  $D^*$ , single or serial countermeasures to be used are group shielding, applied shielding of vehicles, and reduction of travel time. If  $D_2 > 0.5 D^*$ , the use of all three of these measures will probably be necessary. In some cases it may be possible to postpone the initiation of travel, thus reducing the requirements for peripheral countermeasures.

Peripheral countermeasures are not required (but may be advisable) if  $D_3$  (dose at the secondary site) is less than  $0.2 D^*$ . If  $D_3$  is from 0.2 to 0.5 of  $D^*$  and go-time is more than 3 days, applied shielding for living and work areas and scheduling of activities in higher intensity areas (with possibly the shelter as a base) should be instituted. For the same radiation constraint but for a go-time of less than 3 days, the necessary reduction in  $D_3$  may be effected by choosing a later go-time.

Finally, in step 6, the total dose, recalculated on the basis of using peripheral countermeasures, indicates whether the effort would be successful, helpful, or useless.

The decision procedures in Chart 4 are based upon the more probable radiological situations which might be encountered. If unusual circumstances are encountered, the use of Chart 4 might lead to misinterpretation. For example, heavy fallout arriving after  $H + 12$  hr could cause overexposure to shelter occupants despite the fact that this contingency is not considered in Chart 4. However, such errors should be detected, and corrective action taken, when total estimated dose (step 6) is evaluated.

A decision procedure designed specifically for field use, and using observed dose and dose rate inputs, has been developed. This field decision procedure is discussed in Section 6.

#### REQUIREMENTS FOR PREATTACK PLANNING

The implementation of peripheral countermeasures in the postattack period may depend upon, and can certainly be expedited by, preattack planning. Pre-attack planning allows not only a consideration of the type and scope of problem which might be encountered after attack, but also allows accumulation of vital information (in a real sense an "information bank" which is drawn upon only in an emergency). The value of preattack planning in providing the best possible information for postattack use is shown in Fig. 1 for two cases of interest: radiological parameters (which would affect the dose constraints and hence the requirements for peripheral countermeasures) and resources

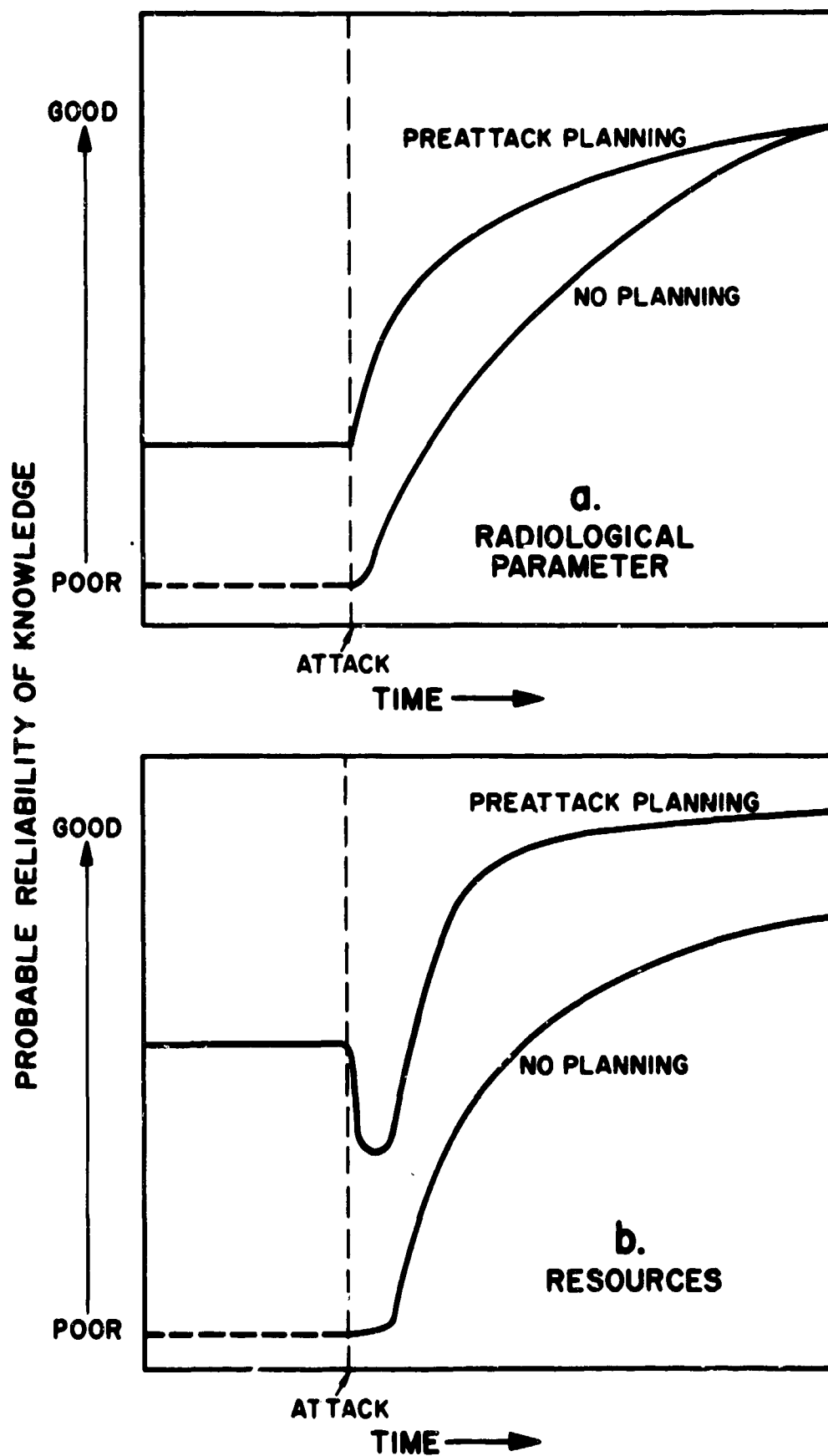


Fig. 1. The Reliability of Knowledge As a Function of Time Information Is Obtained After Attack for Two Levels of Planning

(which are needed for implementing peripheral countermeasures). In Fig. 1a, for radiological parameters, the "no planning" curve depicts a situation in which radiological information is accrued only from the time of attack. Since no preconceived estimate of possible levels of fallout and their possible effects on operations would be available, postattack operations would have to evolve as observed radiological inputs became available. Such inputs might be available only for isolated locations and assessment of the radiological situation, and attendant requirements for peripheral countermeasures might be delayed until more complete coverage was available. On the other hand, preattack planning, in which possible attack patterns had been considered, would establish an information base from which to proceed, so that even with minimal postattack input, some concept of the action required would be available. Preliminary inputs could, of course, lead to erroneous conclusions, but would be amenable to correction as more data became available.

In Fig. 1b, the "no planning" case depicts a situation in which the requirements for and availability of resources for support of peripheral countermeasures is not considered until the attack has occurred. In such a situation the probable location of necessary resources must be determined (possibly from memory or from the classified telephone directory), and then a reconnaissance must be conducted to determine how the desired resources survived the attack. Alternatively, a reconnaissance could be conducted which would combine the inventory and damage assessment functions. In either case, however, the requirements are not well defined, location of resources might be nebulous, and the reconnaissance could not proceed as smoothly as if it had been preplanned. For preattack planning, in which requirements have been well defined and a resource inventory has been completed, the post-attack effort primarily involves a planned reconnaissance to assess the damage to the desired resources. Although the effects of the attack perturb the preattack inventory temporarily (the "slump" in the curve), the damage assessment could be conducted with a minimum of waste effort since the location of the resources is known, and reliable data on surviving resources could become available in short order. Also, because of the preattack inventory, more obscure stocks of resources, which might otherwise be overlooked, would be located and, if undamaged, utilized.



In summary, the "no planning" case provides no conceptual basis on which to consider postattack problems and consequently may delay the implementation of peripheral countermeasures to some considerable degree. Preattack planning does provide such a conceptual basis and would do much to assure the successful and timely employment of peripheral countermeasures after an attack.

Preattack planning for peripheral countermeasures involves additional effort on the part of both the local civil defense organization and the shelter manager. The amount of such effort is not great and can largely be absorbed in existing programs and/or incorporated in the training material left in the shelter for the guidance of the shelter manager. The basic steps in planning for peripheral countermeasures are:

1. Prepare an inventory of resources for the entire community.
2. Assign jurisdiction over an activity zone to each shelter or shelter cluster.
3. Integrate information on the use of peripheral countermeasures into civil defense operational plans.

Designation of activity zones requires a change in the modus operandi of the EOC so that responsibility for action, particularly at early times, can be delegated to the lowest possible echelon. Reassignment of many of the responsibilities presently inherent in the EOC can be done without any major reorganization of the local civil defense organization and might require little more than directives to this effect. However, the extent to which authority is delegated should be clearly stated and areal and time limitations clearly defined. Since establishment of activity zones is a complex procedure, it should be preceded by the community-wide inventory so that boundaries could reflect resource distribution. The local civil defense organization is probably not adequately staffed to undertake such tasks but could establish criteria and procedures, and rely on the staffs of other municipal departments to obtain the desired information. For example, the fire department could be asked to search the files of the individual firehouses, using on-duty firemen as available; the estimated effort involved in such a survey is about 1 man-day per firehouse or less than 10 man-days per 100,000 population.

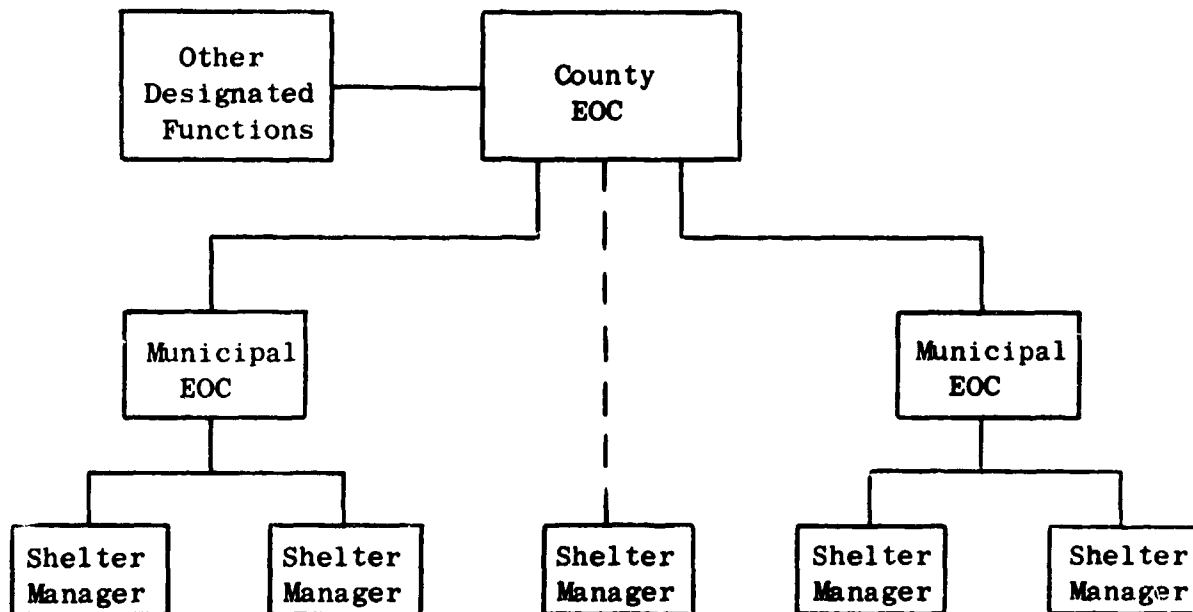
It is estimated that similar information could be obtained from existing firms at a cost of under \$200 per 100,000 population. The local civil defense organization would still have to collate the inventory lists and would probably have to prepare, using their own staff, an inventory of alternate shelters and refuges from the Phase I and II NFSS printout. However, if the inventory is scheduled over some extended period, the workload should not be excessive.

Planning and zoning commissions might be of assistance in establishing boundaries for activity zones, although the EOC staff might prefer to undertake this task themselves. Once the initial inventory and zoning had been completed, the workload would be limited to preparing modifications to inventory lists.

Establishing new operational procedures is not enough; such procedures must be promulgated so that the ultimate user understands their use and the benefits for him. Under the proposed changes, the EOC would become intimately involved, and so would have some understanding of the concepts involved. However, shelter managers, who would be most affected by these changes, would receive little or no instruction. Some training undoubtedly could be incorporated into shelter manager training courses but would probably serve only as an introduction. The use of national civil defense training exercises to orient shelter staff members in the use of peripheral countermeasures might be considered, as might the establishment of special courses for this purpose. However, in lieu of such programs, each shelter should be provided with a map outlining its activity zone, an inventory of resources in the activity zone, and literature and decision aids describing the use and implementation of peripheral countermeasures. Such a package, although not as satisfactory as preattack training in the use of peripheral countermeasures, would allow their incorporation into postattack operations.

#### RESPONSIBILITY AT VARIOUS ECHELONS

Planning for and implementation of peripheral countermeasures can conceivably be carried out at either the municipal level or the local level (i.e., the shelter) under present concepts (sketched below).



The shelter manager (or if many shelters are located in close proximity, a shelter cluster manager) is responsible for in-shelter operations but seeks the guidance of the municipal EOC (or the county EOC in lieu of a municipal EOC) for any operation external to the shelter itself. In turn, the municipal EOC is responsible for actions within municipal boundaries but must seek guidance from the county EOC for operations outside these boundaries. In theory then, the county coordinates operations between municipalities, and the municipality coordinates operations between shelters. In practice, this framework requires that the municipal EOC coordinate the activities of hundreds of shelters, while the county EOC coordinates the activities of a handful of communities. The possible extent of the workload on the municipal EOC has caused some concern and consequently has been studied recently by SRI (Ref. 17). As a part of this study, which gives an excellent description of the EOC operations, simulation techniques were used to test the ability of the EOC staff to receive and act on inputs from many shelters over a short period of time. For the conditions assumed it was concluded that the decision-making capabilities of the EOC were not overtaxed. Despite these findings, however, it might be unwise for individual shelters to rely upon the guidance of the EOC because of the following possibilities:

- The EOC could be overwhelmed by requests (consider 25 shelters asking for guidance simultaneously).

- The communications net might be overwhelmed, inoperative, or damaged.
- Reliance upon the EOC might destroy initiative at the shelter level (i.e., rather than seeking expedient solutions - which might not even be recognizable by the EOC - turning immediately to the EOC).

A suggested alternative to the EOC as the central authority is a system whereby responsibility is delegated to the lowest possible echelon, in this case the shelter. This concept, which is commonly practiced in business, would allow the shelter to be autonomous under specified conditions and at specified times and would greatly reduce the decision and planning load at the EOC. However, if a shelter is to assume a considerable degree of responsibility for its own conduct and safety, its physical boundaries must be extended beyond the shelter walls or shelter building so that supplies and equipment necessary for implementing peripheral countermeasures can be made available. For this purpose, an activity zone should be designated for each shelter or shelter cluster on the basis of radial distance, resources, and population. The activity zone would, hopefully, meet the following criteria:

1. Extend a minimum of 6 blocks from the shelter in at least one direction (to permit some freedom of movement) and a maximum of 2 miles (to avoid excessive travel)
2. Contain alternate shelter or refuge spaces equivalent to at least the peak population
3. Contain food and water stocks capable of supporting the peak population for at least 14 days.
4. Contain sufficient transportation to move the entire shelter population

Additionally, it is desirable that the activity zone contain a source of building materials, heavy equipment, and one or more vital facilities. To achieve these criteria, readjusting of boundaries may be necessary, and portions of the community may remain unassigned, but the net result would be to provide the shelter manager with the capability to respond rapidly to changing conditions and requirements.

## Section 5

### INFORMATION REQUIREMENTS AND SOURCES

The implementation of peripheral countermeasures can be successfully undertaken only if information of both a radiological and operational nature is available. The exact information required varies for each situation, as does the possible source of such information, as shown previously in Chart 2. Tables 3 and 4 list in some detail, for a number of situations, the information requirements and possible sources of information for both preattack and postattack situations. From Table 3, which is concerned with general information, it can be seen that the primary preattack information sources are hypothetical attacks and war gaming, procedures which are used in nationwide civil defense tests and which could readily be applied to local planning. Such war gaming, carried out by the municipal EOC using attack predictions issued by national planners, could, as previously shown in Fig 1a, improve the readiness of the EOC for an actual attack by pointing up weaknesses, testing proposed procedures, etc.

Table 4 lists some of the requirements for information specific to individual peripheral countermeasures. For preattack planning, such information can best be obtained from a community-wide resource assessment, described fully in Appendix F, which will then provide an inventory of essential services and resources. The value of a preattack inventory has been discussed in Section 4.

A pilot resource assessment for selected areas of two communities (Oakland, California and Montgomery County, Md.) was conducted to determine what information was available and the possible source(s) of such information. On the basis of these pilot studies, which are reported in Appendix C, it is concluded that most of the information of interest is currently available, although from several different sources, and could be collected and cataloged without undue expenditure of effort. For example, data on shelters, alternate shelters, and refuges

Table 3  
REQUIREMENTS FOR AND SOURCES OF GENERAL INFORMATION

Requirement	Information	Source of Information		Applicable † Peripheral Countermeasures
		Preattack	Postattack	
Hazards which necessitate untimely emergence from shelter or refuge	Fire spread	"War-gaming" as to results of possible attacks on the community	1) Observed by shelter 2) Warned by EOC	1
	Blast damage to shelter			
	Flooding			
	Overcrowding in shelter			
Determination of dose while in shelter or refuge	Time of fallout arrival	Hypothetical attack	Observed in shelter	2, 3
	Reference dose rate in shelter	Hypothetical attack	Observed in shelter	
	Time of emergence from shelter	War-gaming	Calculated or specified	1, 4
	Determination of dose while traveling	Reference dose rate while traveling	Hypothetical attack	Reconnaissance from shelter or EOC
Determination of dose while at secondary site	Travel time	War-gaming	Assessment of routes, distance, and transportation	1, 4
	Reference dose rate at secondary site	Hypothetical attack	Reconnaissance from shelter or EOC	1, 2, 3, 4
	Duration of stay at secondary site	War-gaming	Specified by circumstances	1, 4

- † 1: Postattack evacuation  
 2: Applied shielding  
 3: Dose Equalization  
 4: Exposure scheduling

**Table 4**  
**REQUIREMENTS FOR AND SOURCES OF SPECIFIC INFORMATION**

Requirement	Information	Source of Information	
		Preattack	Postattack
Life saving at very early times	Location and effectiveness of shelters and refuges	Inventory w/estimated PF (NFSS, EOC data)	Inventory and reconnaissance
	Food and water resources (for refuges)	Resource inventory	Inventory and reconnaissance
Capability to evacuate	Best route	War-gaming	Reconnaissance or EOC directive
	Trafficability (debris, fire, etc.)	War-gaming	Reconnaissance or EOC directive
	Heavy equipment (for debris clearance)	Resource inventory	Inventory and reconnaissance
	Transportation available	Resource inventory	Inventory and reconnaissance
	Candidate secondary sites	Resource inventory	Inventory and reconnaissance
	Food and water	Resource inventory	Inventory and reconnaissance
Applied shielding	Shielding materials	Resource inventory	Inventory and reconnaissance
	Light and heavy equipment	Resource inventory	Inventory and reconnaissance
	Manpower	Resource inventory	Inventory and reconnaissance
Exposure scheduling	Duration and frequency of necessary task	War-gaming	Reconnaissance

are available in the files of the EOC; data on resources used directly or indirectly in support of peripheral countermeasures can be obtained either from files within city departments (such as the fire department) or from commercial sources (such as city directories). A procedure for undertaking such a resource analysis is given in Appendix F.



## Section 6

### RADIOLOGICAL AND OPERATIONAL CONSIDERATIONS

#### PLANNING AIDS AND PROCEDURES

Control of exposure is the primary objective of peripheral countermeasures and, in support of this objective, it is necessary to have planning aids and procedures which will allow accurate prediction of dose under many situations. Procedures which fulfill this requirement for both preattack planning and postattack implementation have been developed and are discussed in detail in Appendix B. Two concepts, equivalent residual dose (ERD) and accumulated dose, have been investigated, and a correlation between the two, which considers the effects of go-time and the dose rates in the primary (i.e., shelter) and secondary sites, has been prepared (Table B-1). Thus, accumulated dose, which has been found to be more amenable to postattack use (both because of its relative simplicity and its direct correlation with observed dose), can be corrected to reflect the refinement offered by the ERD concept.

Planning aids (Figs. B-2, B-3, and B-4) which permit the direct determination of ERD for one- and two-stage environments have been prepared and are useful when the shelter stay is lengthy (a one-stage environment) or local reoccupancy of the area immediately around the shelter (two-stage environment) is practiced. However, for a three-stage environment (shelter, travel, and secondary site), a nomograph which utilizes accumulated dose must be employed (Fig. B-8). This nomograph is very versatile and allows observed dose to be used whenever available. The estimated dose for any of the three environments can be quickly calculated and the results used to verify the more general guide lines given on Chart 4. Figure B-8 can also be used to estimate total dose, or to determine the limiting dose rates or times for any of the environments. Since Fig. B-8 can be used to quickly and accurately estimate dose for complex cases, it is well adapted to assessing the several options which may exist for the use of peripheral countermeasures in a given situation.

Further refinements of this particular planning aid which would further simplify its use by local civil defense personnel should be considered.

For postattack use, planning aids should utilize both dose<sup>1</sup> and dose rate as inputs and should provide procedures which allow the rapid evaluation of possible action options. Figure 2 is an example of a decision procedure for postattack use; criteria for use are that (1) all radiological inputs are obtained at or projected to  $H + 12 \text{ hr}^2$  and (2) total dose should not exceed 200 r (ERD). The total dose is the sum of the observed dose in the shelter ( $D_1$ ) and the potential dose either from remaining in the shelter (i.e., the observed shelter dose rate,  $r_1$ , multiplied by the DRM for peak ERD from Fig. B-2), or else from dose while traveling ( $D_2$ ). The various possible combinations of these doses define the possible action options, which may include one or more of the following:

- a. Evacuate to a free zone immediately.
- b. Stay in the shelter for 2 weeks and then evacuate to a free zone.
- c. Stay in the shelter for 2 weeks, using all available peripheral countermeasures, and then evacuate to a free zone.

The use of Fig. 2 is as follows:

1. Determine the dose rate,  $r_1$ , within the shelter at  $H + 12 \text{ hr}$ . Draw a line on Fig. 2 from the appropriate value for  $r_1$  (the right-hand margin), thus defining regions I and II, III and IV. [Note that  $(r_1 \times \text{DRM}) + D_1 = 200 \text{ r (ERD)}$ ].
2. Determine potential free zones or high-protection shelters, travel route, mode of travel, and estimate travel time,  $T_2$ .
3. Measure or estimate the dose rate,  $r_2$ , along the proposed travel route.
4. Determine travel dose,  $D_2$ , by drawing a line from  $r_2$  through  $T_2$ .

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<sup>1</sup> The use of observed dose (which is a measure of dose rate over time) offers a decided advantage since it eliminates possible errors in judging time of arrival of fallout and errors caused by variations in rate of decay of the fallout.

<sup>2</sup> Decision procedures for other times can easily be prepared.

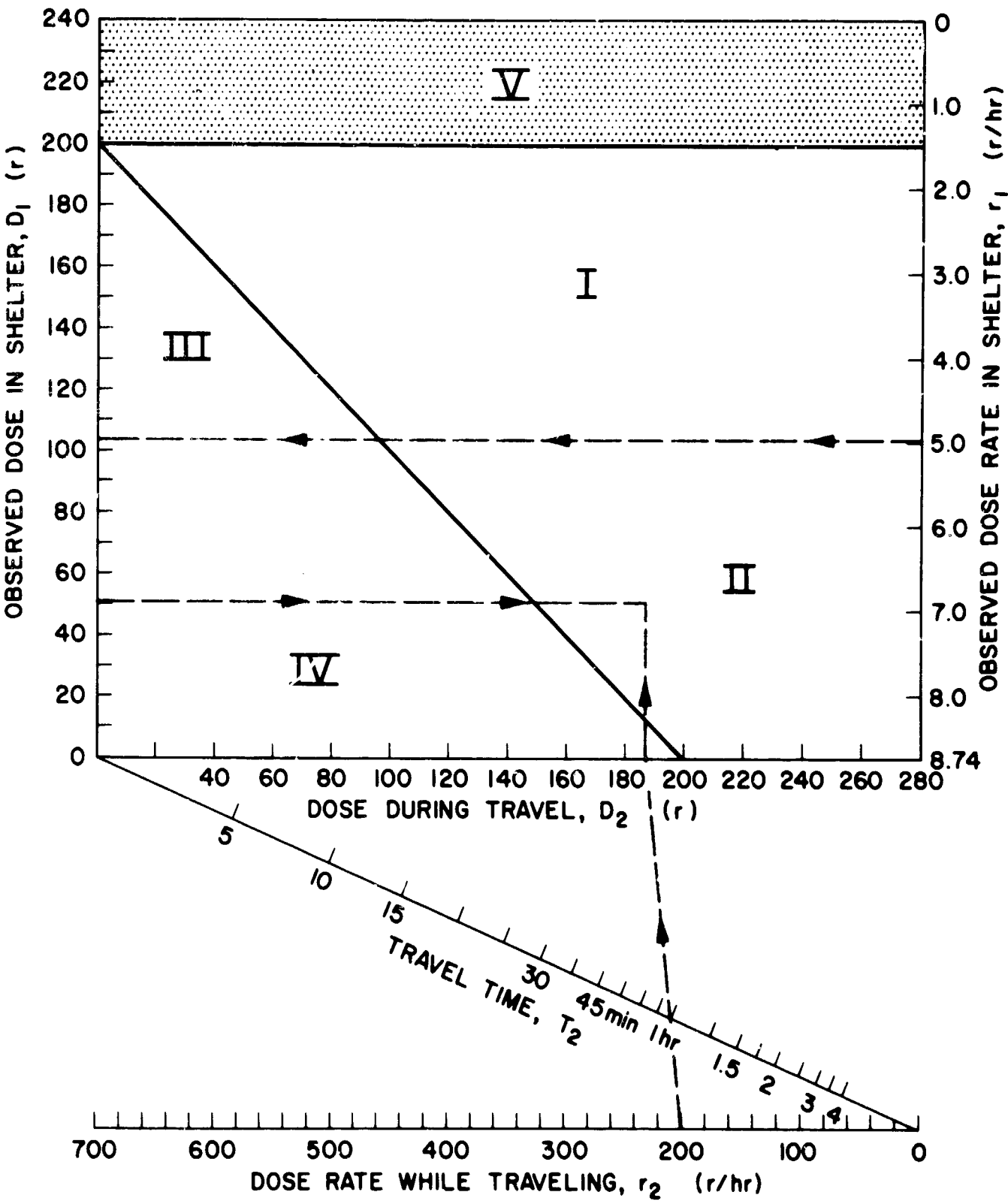


Fig. 2. Evaluation Procedure Using Observable Radiological Input

5. Determine the accumulated shelter dose,  $D_1$ , to  $H + 12$  hr and note appropriate value on left-hand margin.
6. Extend lines from  $D_1$  and  $D_2$ ; the intersection defines the action option as explained in Table 5.

An example of the use of Fig. 2 is given below:

Observed at  $H + 12$  hr:       $r_1 = 5.0$  r/hr  
     $D_1 = 50$  r

Estimated at  $H + 12$  hr:       $r_2 = 200$  r/hr  
     $T_2 = 1$  hr

Constructing lines as shown, it is found that the action option of region II is applicable, i.e., evacuation at 2 weeks to a free zone is acceptable, but the use of peripheral countermeasures is not essential. However, the use of peripheral countermeasures is desirable in order to reduce dose as much as possible, rather than receiving the maximum value of 200 r (ERD).

Table 5  
 APPLICABLE ACTION OPTIONS  
 (For Fig. 2)

Region	Action Option	Radiological Constraint
I	Remain in shelter and initiate all possible peripheral countermeasures; evacuate to free zone at 2 weeks.	Total dose exceeds 200 r for 12-hr evacuation or for "normal" shelter occupancy.
II	Remain in shelter for 2 weeks and then evacuate to free zone.	Dose exceeds 200 r for 12-hr evacuation.
III	Evacuate at $H + 12$ hr to free zone. <sup>†</sup>	Total dose exceeds 200 r for "normal" shelter occupancy but less than 200 r for evacuation at 12 hr.
IV	Evacuate to free zone at $H + 12$ hr or at $H + 2$ weeks. <sup>†</sup>	Total doses for both options less than 200 r.
V	Serious overexposure probable. Initiation of peripheral countermeasures may reduce the extent of the radiation damage.	Total doses for any option greatly exceed 200 r.

<sup>†</sup> Long-term peripheral countermeasures, such as applied shielding, may be employed to reduce the dose to shelter occupants.

Figure 2 is intended to provide a rapid decision procedure and of necessity is limited to a few possible action options. Other possible action options can be evaluated using the more sophisticated planning aids included in Appendix B. Other action options which might be considered include evacuation at a somewhat later time (utilizing the "optimum go-time" principle described in Ref. 1) and movement to other nearby protected locations. Figure B-8, which can accommodate both observed dose and dose rate inputs (as described in Appendix B), can be used for such detailed evaluations.

#### EFFECTS OF VARIOUS PARAMETERS ON DOSE

Not all of the parameters which must be considered for an evaluation of the radiological situation are equally important. The relative importance of various parameters is shown in Figs. 3 and 4 for two-stage environments for which an ERD of 200 r has been established. From these figures it can be seen that, if the PF of the shelter is adequate (i.e., falls to the right of the diagonal line marked "ERD Exceeds 200 r"), increasing its PF has little effect on the allowable reference intensity.<sup>3</sup> However, if the PF of the shelter is inadequate, overexposure (to an ERD greater than 200 r) will occur regardless of the go-time or the PF after emergence.

Figure 3 shows that, when the shelter is adequate, the go-time has an appreciable effect on the allowable reference intensity. Thus, if the situation permitted, staying in the shelter for 28 days rather than 7 days would increase the allowable reference intensity, for a shelter PF = 1,000, from 1,200 r/hr to 2,800 r/hr. If the reference intensity were 1,200 r/hr initially, this same delay would effectively reduce dose received by a factor of  $2,800/1,200 = 2.3$ .

If release from the shelter at 14 days were preferred to a delay, the use of applied shielding to increase the PF after emergence would have a striking effect (see Fig. 4). In the case where shelter PF = 100, raising

<sup>3</sup> The allowable reference intensity, which is used here as a convenient index, is directly proportional to dose. Taking an example from Fig. 3 for go-time = 14 days, PF of the shelter = 100 and reference intensity = 1,700 r/hr, the ERD is 200 r. Reducing the reference intensity to 850 r/hr would reduce the ERD to 100 r.

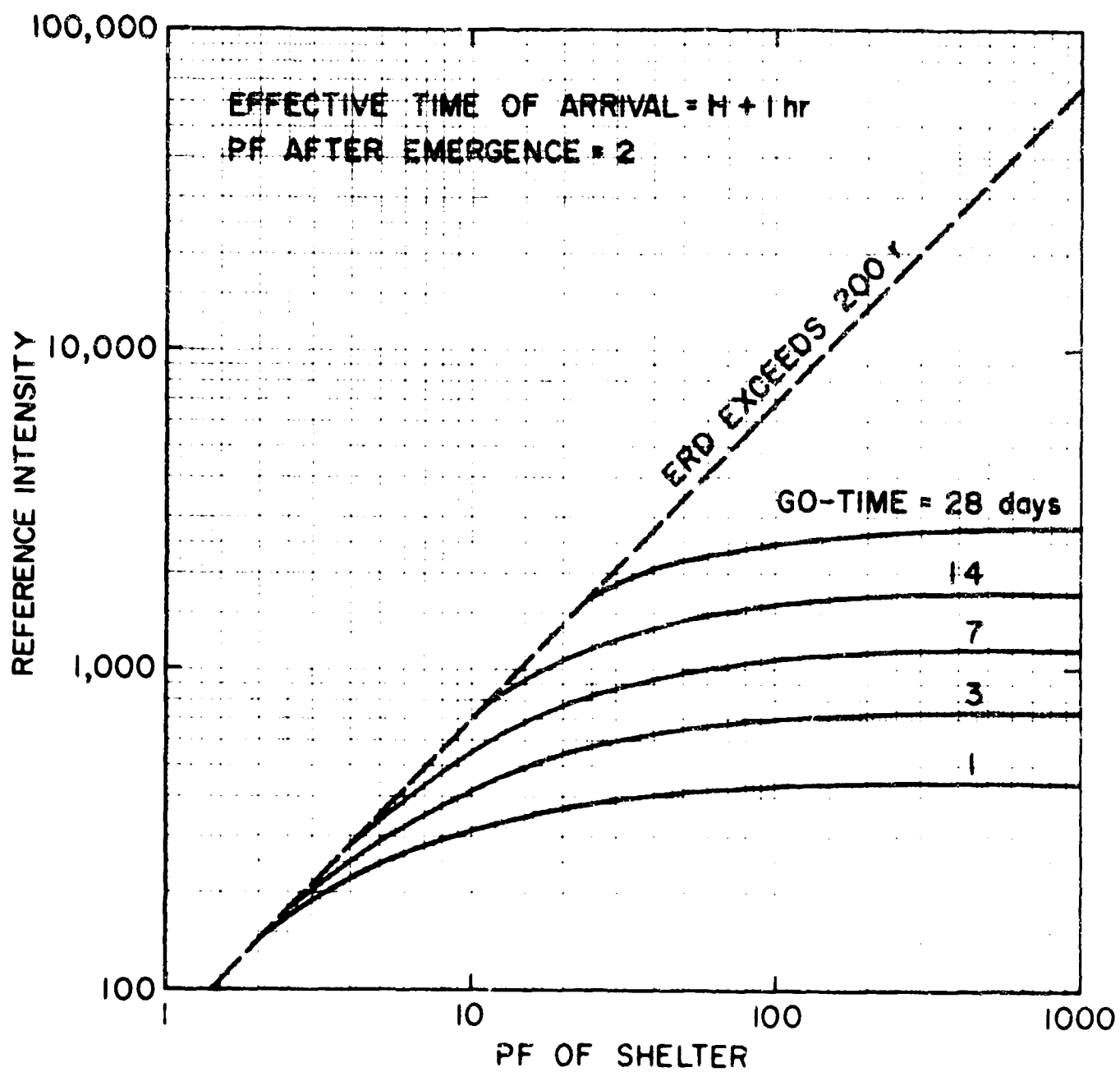


Fig. 3. Reference Intensity vs PF for Several Times of Emergence

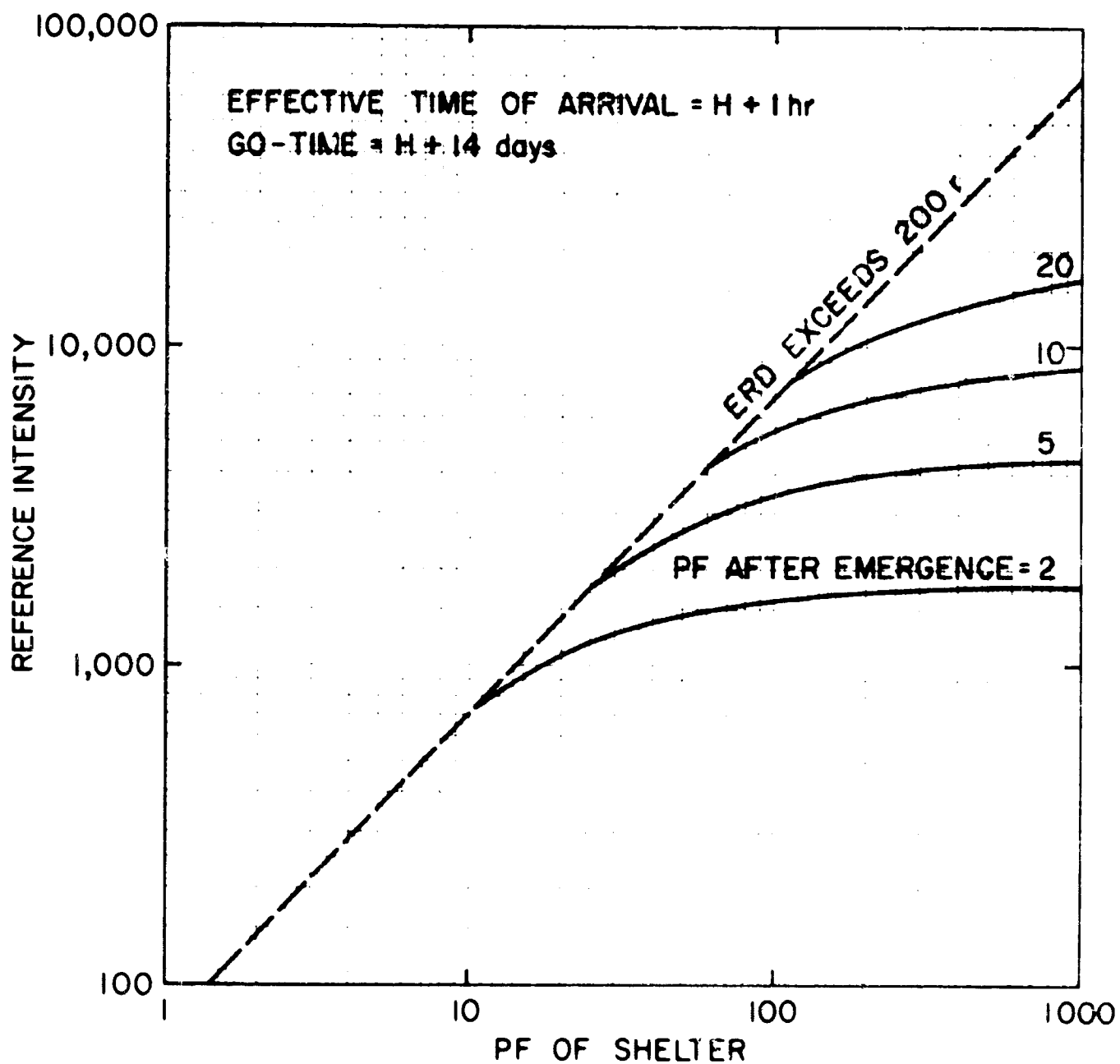


Fig. 4. Reference Intensity vs PF of Shelter for Several Values of PF After Emergence

the PF after emergence from 2 to 10 would have the effect of raising the allowable reference intensity from 1,600 to 5,500 r/hr or, conversely, of reducing dose by a factor of 3.4.

A three-stage environment is even more complex, but two parameters which may be pursued less rigorously are shown, by Figs. 5 and 6, to be: effective time of arrival and travel time. Figure 5 shows, for four different cases, that effective times of arrival of fallout ranging from 0.5 to 10 hr after attack cause differences in dose of from 28 to 64 percent; these variations are directly related to the relative fraction of the total dose received during the shelter phase. The importance of these curves, from practical considerations, is that generally great accuracy is not required in determining the value of effective time of arrival. Except where the dose rate within the shelter approaches tolerable limits, estimation of effective time of arrival within  $\pm 1$  hr is adequate.

Figure 6 shows that peak ERD for a three-stage environment is relatively insensitive to travel time for go-times greater than 24 hr; this nondependence is true because the peak ERD is produced either by the shelter dose or the dose after emergence. Travel time becomes important, for the radiological conditions listed, only at very early go-times; even then the variation between travel times of 15 min and 4 hr is only 75 percent. In general, travel time does not need to be known with great accuracy except when (1) a very early go-time is necessary and/or (2) the dose received during travel is greater than 50 percent of the total allowable dose.

#### Time Saved

The use of peripheral countermeasures can result in the earlier initiation of a desired action, resulting in a time-saving payoff. In the time frame of the early postattack period, the time saved may be only a few hours; but in terms of a necessary action, such as moving from a fire-threatened shelter, this saving may represent the difference between life and death. Assessment of the value of time saved requires a detailed and systematic analysis, which has not been attempted in this study. However, any analysis



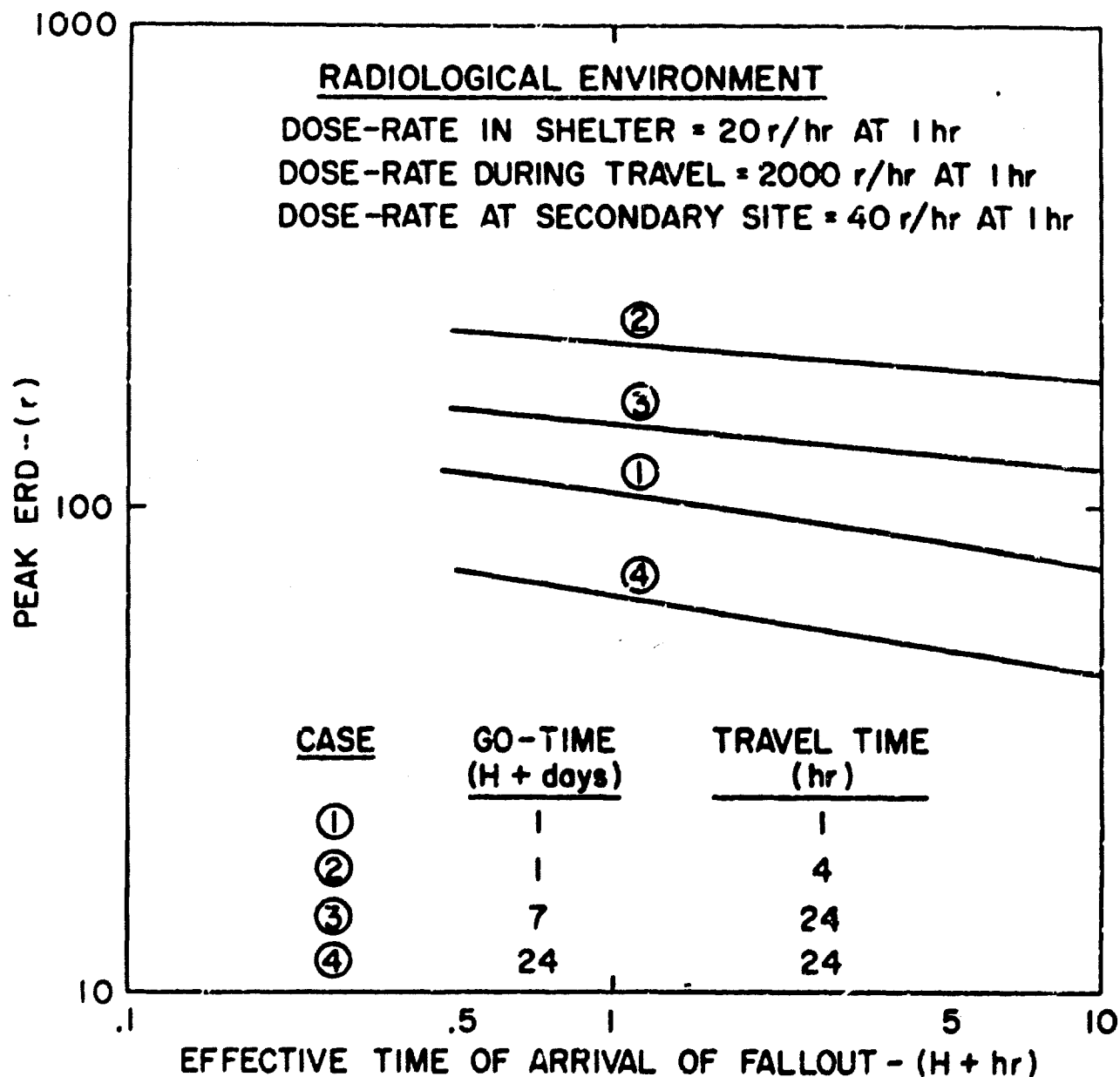


Fig. 5. Peak ERD vs Effective Time of Arrival of Fallout for Several Go-Times

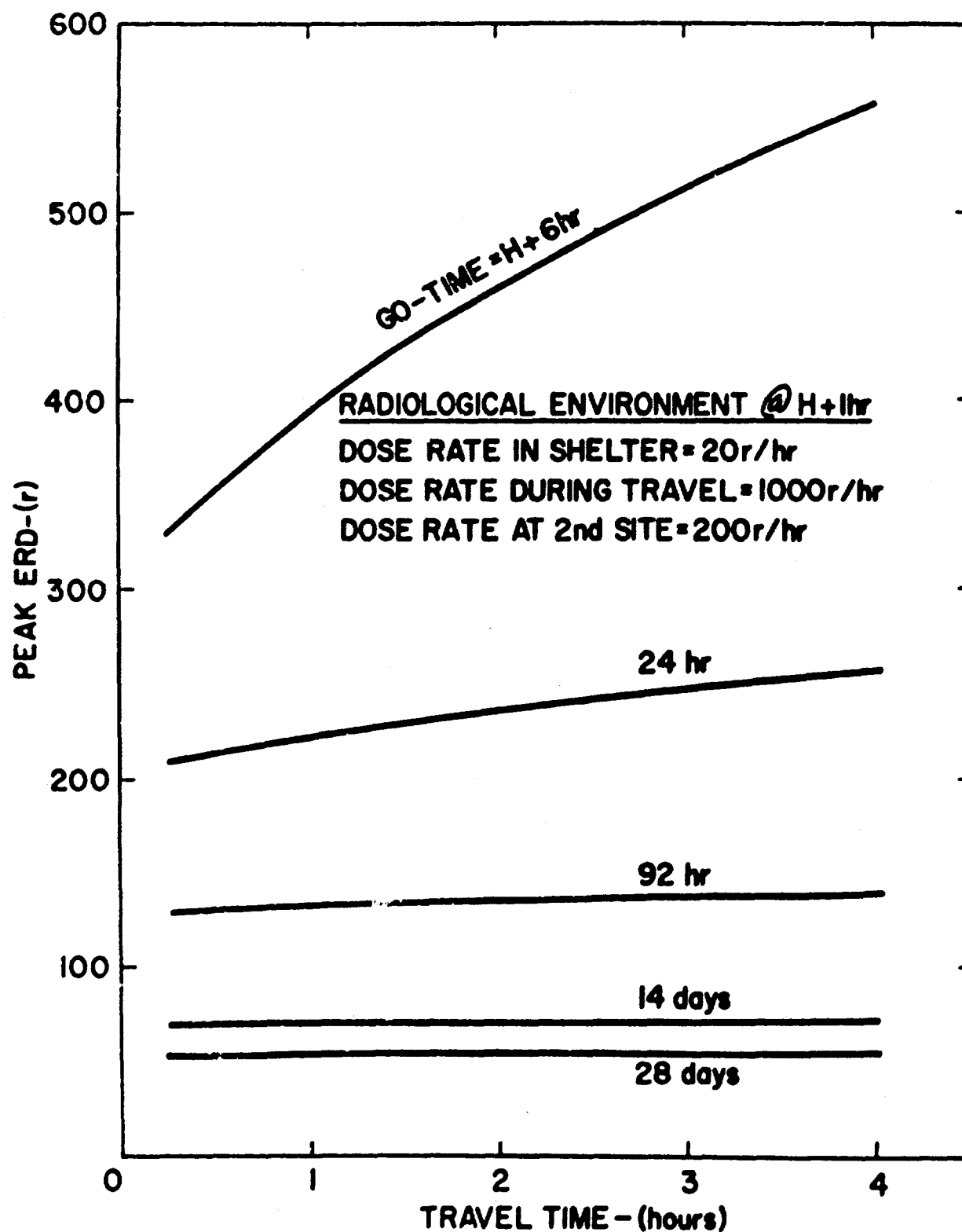


Fig. 6. Peak ERD vs Travel Time for Several Go-Times and a Given Radiological Environment

of dose can easily be repeated, with modifications, to determine what time savings might be effected. For example, if the movement of operating personnel into a power generating station was found to be safe at  $H + 7$  days, another calculation in which applied shielding (using available materials) was considered, could drop the entry time to  $H + 3$  days, a savings of 4 days. However, such time savings could not be realized unless necessary support were available. In general, time savings would be secondary to dose constraints and other operational limitations.

A recent RTI report (Ref. 18) investigated the effects of decontamination on time saved; both ERD and accumulated dose were considered in their calculations. Typical results, which are limited to one-stage movement where personnel move from a free zone into the contaminated area and there reduce the radiation field through the use of a countermeasure, are shown in Table 6. Of equal, and sometimes greater, interest than time saved is the earliest entry time which establishes when a mission can be started. For example, decreasing the entry time from 4 days to 2 days may be unimpressive with respect to time saved, but may represent the difference between the success and failure of a given mission.

Figure 3, previously discussed, can be used to illustrate time saved for a two-stage movement. For example, if peripheral countermeasures which increase  $P_1$  from 100 to 200 and  $P_2$  from 2 to 4 are used, the go-time can be decreased from 28 days to 9 days, representing a savings of 19 days. Again, though, the most important consideration is the possibility of emerging from the shelter earlier, not the time saving per se.

Table 6  
TIME SAVED AS A FUNCTION OF  
COUNTERMEASURE EFFECTIVENESS

<u>Countermeasure Effectiveness†</u>	<u>Earliest Entry Time (days)</u>	<u>Time Saved (days)</u>
1.0	36.5	—
0.75	25.5	11
0.5	18	18.5
0.25	8	28.5

Conditions: 1. Reference dose rate = 2,000 r/hr  
2. Allowable accumulated dose = 100 r  
3. Stay time is 8 days

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† Countermeasure effectiveness =  $\frac{\text{dose rate with countermeasure}}{\text{dose rate without countermeasure}}$

From Fig. 9 of Ref. 18.

Section 7  
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The major conclusions of this study are that the four peripheral countermeasures studied (postattack evacuation, applied shielding, dose equalization, including group shielding, and exposure scheduling):

- Can save lives, reduce time of emergence from shelter, and/or reduce the dose received under a number of possible attack situations and operational conditions
- Require only a limited degree of preattack planning and preparation to ensure successful postattack implementation
- Are compatible, with only minor modification, with the existing civil defense organization

It is also concluded that:

- Exposure control, although a complex function in the early postattack period (involving, at a minimum, three radiological environments and many action options) can be satisfactorily achieved using the planning aids and procedures reported herein.
- Decision procedures which allow the planner, in either a preattack or postattack situation, to utilize the available information in a logical format, are necessary adjuncts for the successful use of peripheral countermeasures.
- Some modification of the operational and management aspects of the present local civil defense will be required if the best utilization of peripheral countermeasures is to be realized. These modifications include requirements for a preattack inventory of resources necessary for the support of peripheral countermeasures, designation of activity zones within the municipality, and reassignment of responsibility for local action from the EOC to the shelter or shelter cluster.
- A degree of preattack planning is required for the best utilization of peripheral countermeasures. Peripheral countermeasures would still have value, but would be considerably less effective, if reliance were placed entirely upon postattack implementation.

- The local civil defense organization can, with some assistance from other municipal functions, readily assimilate the additional planning and implementation load imposed by the introduction of peripheral countermeasures.

## RECOMMENDATIONS

On the basis of this study it is recommended that an additional study be undertaken to confirm, within a "realistic" framework, the conclusions concerning the impact on the existing local civil defense organization of the requirements for preattack planning and postattack implementation associated with peripheral countermeasures. Further, such a study would investigate the relationship of peripheral countermeasures to other exposure control procedures such as remedial movement, shelter improvement, and decontamination.

It is specifically recommended that the proposed study have the following objectives:

1. To evaluate and measure the performance and practicality of peripheral countermeasures for selected areas of several cities
2. To determine for each of the cities studied the interrelationship between peripheral countermeasures and other countermeasures involving exposure control
3. To develop and evaluate for the cities studied possible organizational and management concepts that may improve the performance of peripheral countermeasures
4. To develop conclusions regarding the manner in which peripheral countermeasures can best be introduced into existing civil defense planning, how the best payoff can be realized, and the limiting conditions for using peripheral countermeasures

Deficiencies noted in this report on the state of the knowledge about or related to peripheral countermeasures suggest that theoretical and/or experimental studies be undertaken in the following areas:

1. The value of group shielding techniques in shelter configurations in below-grade or upper-story locations.
2. The extent of inhomogeneities of initial fallout deposition patterns introduced by local terrain features and micrometeorological conditions.

3. The extent of redistribution of initial fallout patterns by subsequent weathering action.
4. The effects of inhomogeneous fallout distribution on the protection afforded by various shelter configurations.

## Section 8

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## Appendix A

### PROCEDURES FOR THE USE OF PERIPHERAL COUNTERMEASURES

The modus operandi of peripheral countermeasures has been discussed in Section 3. This appendix will consider engineering support, effort, operational problems, etc. of the individual peripheral countermeasures and is intended to provide a basis for planning and implementing peripheral countermeasures.

#### POSTATTACK EVACUATION

The basic mechanism of evacuation is the movement of personnel from the shelter along a travel route to a secondary site. The major operational problem is the movement of a large number of persons over a considerable distance as expeditiously as possible. The first determination that must be made is the route to be taken and the trafficability of the route. Establishment of possible evacuation routes should be a part of preattack planning and should consider possible postattack hazards, including collapsed bridges, unusual debris levels from adjoining built-up areas, abandoned cars, etc. By careful consideration of such factors, routes which have a better-than-average chance of being usable after attack can be selected and so designated in the civil defense plan for the community.

The second major determinant for movement of people is the availability and characteristics of transportation. It is probable in most locations that cars will be the most readily available form of motorized transportation (especially where people have driven their cars to a shelter), although buses and trucks may be available in some activity zones. In some very unique situations, where the terminals are located close to the shelter, ships or trains might also be used for evacuation purposes. However, these latter two forms of transportation must be considered with caution, since their use implies a need for a three-stage evacuation, i.e., from shelter to terminal, from terminal to train, and from train to destination. Motor vehicles, on the other hand, can normally be driven up to the shelter entrance and people loaded

directly into them. Foot travel, although having many undesirable characteristics, is even less complicated with respect to scheduling and implementation.

The number of vehicles which might be needed for mass movement of personnel is shown in Table A-1. Automobiles, because of their small capacity, would be required in much greater number than other vehicles and could create traffic problems, much as in a peacetime situation. However, because of their probable availability, cars may be the obvious choice. Trucks and buses, when available, would preferably be used because, as in any transportation system, people can be moved more efficiently in larger units. Although trains possess a high potential for mass evacuation, and have been shown to be a potent factor in strategic evacuation (Ref. 19), they would probably not be used because of the factors listed in the previous paragraph.

Table A-1  
CAPACITY OF VEHICLES FOR MASS MOVEMENT OF PERSONNEL

<u>Vehicle Type</u>	<u>Passenger Capacity</u>
Automobile	6 - 10
Truck, 2-1/2-ton	35 - 50
Bus	40 - 70
Truck, semi	70 - 100

Evacuation plans must also recognize the trafficability characteristics of the mode of transportation selected, especially as they relate to the postattack environment. Table A-2 lists the estimated effects of several possible environments on various modes of transportation. As debris levels increase and are compounded by weather conditions, motorized transportation becomes very unreliable and, unless debris clearing operations are undertaken, evacuation by foot may be the only recourse. However, in the absence of moderate or heavy debris, bus and truck travel remain attractive procedures.

Table A-2  
POSSIBLE EFFECTS OF SEVERAL ENVIRONMENTAL CONDITIONS ON MODES OF TRAVEL

Environmental Condition	Effect of Environment on: †				
	Foot	Car	Bus	Truck	Train
No debris	1	1	1	1	1
With rain	2	1	1	1	1
With light snow	2	2	2	1	1
With heavy snow	3	4	4	3	4
Light debris (1/2-3 psi): branches, shutters, shingles, nails, etc.	1	2	2	2	2
With rain	2	2	2	2	2
With snow	2	3	2	2	2
Moderate debris (3-6 psi): roofs, tree trunks, overturned cars, etc.	2	3	3	3	4
With rain or snow	3	4	4	4	4
Heavy debris (>6 psi): walls, structural members, etc.	3	4	4	4	4

† Estimated probable effects: 1 = little or none  
 2 = impedes appreciably  
 3 = possibly negates  
 4 = probably infeasible

The radiation protection during travel, which is affected by the mode of travel, must also be considered. Table A-3 lists relative protection factors for several modes of transportation. The protection afforded by motorized vehicles could be increased by the use of applied shielding on the floor or sides of the vehicles, while mutual shielding could be used to increase the protection of the man on foot.

On the basis of number of people to be moved, routes and their conditions, distance, and type and number of vehicles, the travel time can be estimated, and a schedule for emergence from shelter, loading vehicles, and departure can be prepared and implemented.

Table A-3  
RELATIVE RADIATION PROTECTION VALUES FOR  
VARIOUS MODES OF TRANSPORTATION

(Adapted from Ref. 20)

<u>Mode</u>	<u>Relative Protection<sup>†</sup></u>
Man on foot	1
Automobile	1.2
Truck, 2-1/2-ton	1.7
Truck, semi	2

<sup>†</sup> These relative values are directly applicable if the dose rate has been measured in a real fallout field. For preattack planning purposes, these values should be increased by at least 50 percent to account for surface roughness effects (Ref. 14).

#### APPLIED SHIELDING

The implementation of applied shielding requires: (1) a knowledge of the source(s) of radiation so that the best placement for shielding materials can be determined; (2) finding a supply of suitable shielding material; (3) applying this mass to the designated areas and, if necessary; (4) improving the structural characteristics of the building to support this mass. Also of concern, although actually a facet of exposure scheduling, is the dose received by the work crew(s).

Determination of the source of the radiation can be done either empirically or semiempirically, as noted in Section 3, and from these results and from an inspection of the shelter structure, the decision made regarding location and quantity of shielding mass.<sup>1</sup> Also, at this time, requirements for additional structural members to support the additional load must be considered. Schedules can then be prepared, using exposure scheduling and dose equilization as exposure control countermeasures, for obtaining and placing the necessary quantities of material. Any dense material can be used for shielding purposes; however, it should be readily available in the necessary quantities and, preferably, in a form which is easily handled with the manpower and equipment available. Although dirt (particularly in sandbags), brick, cinder block, etc. meet all the density and handling criteria, they are usually not available in appreciable quantities around the more built-up areas where shelters are most commonly found. However, preattack planning which takes cognizance of such possible requirements would list any nearby sources of building materials. Also, in the event that a crash civil defense effort was launched, such supplies, particularly filled sandbags, could be stockpiled at central locations convenient to one or more shelters. Consideration should also be given to dense materials indigenous to the structure itself. Such materials might consist of filled filing cabinets, bulk paper supplies, books, movable partitions, etc. or, as a last resort, desks piled several high.

The placement of additional shielding materials can create uniform floor loads of 50 to 150 lb/ft<sup>2</sup> and concentrated floor loads of up to 600 lb/ft<sup>2</sup>. As a consequence, it may be necessary to provide additional support to floors to prevent failure and collapse. If preattack planning has been adequate, load limits for floors will have been established, tentative bracing procedures developed, and necessary equipment and supplies stockpiled or inventoried. In the event that prior planning has not been done, existing materials would have to suffice. Although 8- by 8-in. timbers are best used for bracing, smaller timber nailed together could be substituted. Such lumber might be available or might be obtained by partial demolition of walls within the structure or adjacent structures.

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<sup>1</sup> In lieu of reliable data on the probable inhomogeneity of fallout distribution following attack, the following discussion assumes a uniform fallout pattern.

As an alternative to structural modification, redistribution of the shielding material load could be considered, e.g., instead of placing 150 lb/ft<sup>2</sup> on the ground floor over a basement shelter, 50 lb/ft<sup>2</sup> could be placed on each of the first, second, and third floors. Although moderate loss in shielding effectiveness could result, such a compromise might be necessary.

The placement of shielding materials within a shelter or refuge building varies for each situation, but some interesting comparisons can be made for simple, idealized cases.

Three cases, similar to those given in Ref. 1 (Figs. 14, 15, and 16), will be used to illustrate the estimated engineering support required for applied shielding for a basement refuge (or shelter), an above-grade basement refuge, and a refuge in the upper floors of a building. Improvement in the PF value, which is dependent on initial PF, and dose to work crews, which is dependent on the dose rate at the work site, cannot be generalized and are not considered here. However, examples are given in Appendix D which illustrate the effects of these two parameters with respect to applied shielding.

#### Below-Grade Basement Refuge

A uniform layer of shielding material is placed over the basement ceiling by a crew of laborers carrying in 50-lb sandbags from just outside the building. (Fork lifts, if available, could speed up this procedure appreciably.)

#### Structural Modification

Place precut 8- by 8-in. timbers as required to support basement ceiling.

#### ESTIMATED EFFORT AND SUPPLIES PER 1,000 FT<sup>2</sup>

	<u>Added Mass (lb/ft<sup>2</sup>)</u>		
	<u>50</u>	<u>100</u>	<u>150</u>
Man-hours (shielding)	33	66	100
Man-hours (structural)	—	1/2	1
Total mass (tons)	25	50	75
No. 50-lb sandbags	1,000	2,000	3,000
No. 8- by 8-in. timbers, 13 ft long	—	<1	1



Above-Grade Basement RefugeShielding Applied

Prepare 2-ft-wide by 4-ft-high dirt embankment around perimeter of exposed basement wall.

- Procedure 1: Bulldozer pushes dirt from immediate vicinity (grass or lightly landscaped grounds) into a windrow around the perimeter.
- Procedure 2: Prefilled sandbags are carried manually and stacked in place. (Fork lifts or trucks, if available, would speed up this procedure appreciably.)

EFFORT AND SUPPLIES PER 100 LINEAR FT OF PERIMETER

	<u>Procedure 1</u>	<u>Procedure 2</u>
Man-hours	1/2	300
Equipment-hours	1/2	—
Mass (tons)	200	200
No. 50-lb sandbags	—	8,000

Refuge in Core Area of Middle Floor of a Tall Office BuildingProcedure

Erect a 6-ft barrier of 50-lb/ft<sup>2</sup> mass, using materials available within the shelter structure. Add 50-lb/ft<sup>2</sup> mass to the floor above the shelter (area covered should be approximately twice that of the shelter area to be shielded).

Structural Modification

No additional supports will be required if load is distributed uniformly.

Source of Mass

The following kinds of materials would be available: filing cabinets, supplies, desks, etc.

## ESTIMATED EFFORT AND SUPPLIES

	<u>Per 100 ft of Perimeter</u>	<u>Per 1,000 ft<sup>2</sup></u>
Man-hours	30	50
Mass (tons)	15	50
No. 200-lb files	150	500

TOTALS FOR A 3,000-FT<sup>2</sup> SHELTER AREA

Total man-hours	350
Total mass (tons)	180

## DOSE EQUALIZATION

Personnel living in the same radiological environment do not necessarily receive the same radiation dose. This anomaly can result because of inhomogeneities in the radiation field or because individuals pursue different activity patterns. An example of the first effect can be noted in any shelter where certain locations afford better protection than do other locations. The second effect is illustrated by an individual who spends some time each day checking the mechanical equipment of the shelter in a high-intensity radiation field as contrasted to another individual who rarely moves from his bunk.

It is desirable to equalize the dose to personnel (with the possible exception of children and pregnant women who might be assigned lower dose limits) in order to preclude gross discrepancies which might result in illness or death to a few and to establish a "dose bank" for future operations. Within the shelter, dose equalization is to some degree accomplished by normal random movement, but it may have to be augmented by planned rotation of personnel between various areas and in various tasks.

The effectiveness of dose equalization procedures should be checked regularly by reading dosimeters which have been distributed randomly to the shelter population and recording the readings. The dose of persons receiving extraordinary amounts of radiation (e.g., members of a survey team or a work

party) should be equalized by subsequently assigning such persons to low-intensity areas and/or by withdrawing them from future work in high-intensity areas.

Group shielding (i.e., the mutual shielding resulting from the close proximity of a number of persons in a radiation field) has been studied by General Technologies Corporation (GTC). GTC calculated (Ref. 2) the effects of group shielding for 96 persons in a 40- by 60-ft ground-level shelter having a PF of 100. With random motion used to equalize the dose among personnel at all locations, the average effective PF for "normal" spacing (25 ft<sup>2</sup> per person) was calculated to be 145; for "shelter grouping" (15 by 15 in. per person), the average effective PF calculated to be 340. GTC concluded that this increase was dependent on the number of people in the group, but independent of the size of the shelter. GTC also studied groups in a "marching interval" (30 by 30 in. per person) in an ideal plane and calculated that an average effective PF of 3.2 (versus a PF of 1 for an individual) would be realized by a group of 96. These data have been plotted in Fig. A-1, showing number of people in the group versus the countermeasure factor (a term proposed by Greene in Ref. 14 as a measure of the improvement effected by the use of the countermeasure). The effective PF is obtained by multiplying the PF for an "ideal" case by the countermeasure factor from Fig. A-1. For example, 100 persons in a shelter can, with shelter grouping, produce a countermeasure factor of 3.3 (Fig. A-1). If the calculated PF of the shelter were 100, the effective PF with shelter grouping would be  $100 \times 3.3 = 330$ .

The GTC data must be used with some reservations because of both recognized limitations and unknown, but potential, deviations. For example, random movement to equalize dose is generally recommended; however, if the average dose received with random movement were just above the lethal range, resulting in the death of most or all persons, a static grouping, which would result in a continuum ranging from "safe" to "certain death," would be preferable because more lives would be saved. Further, GTC considered only

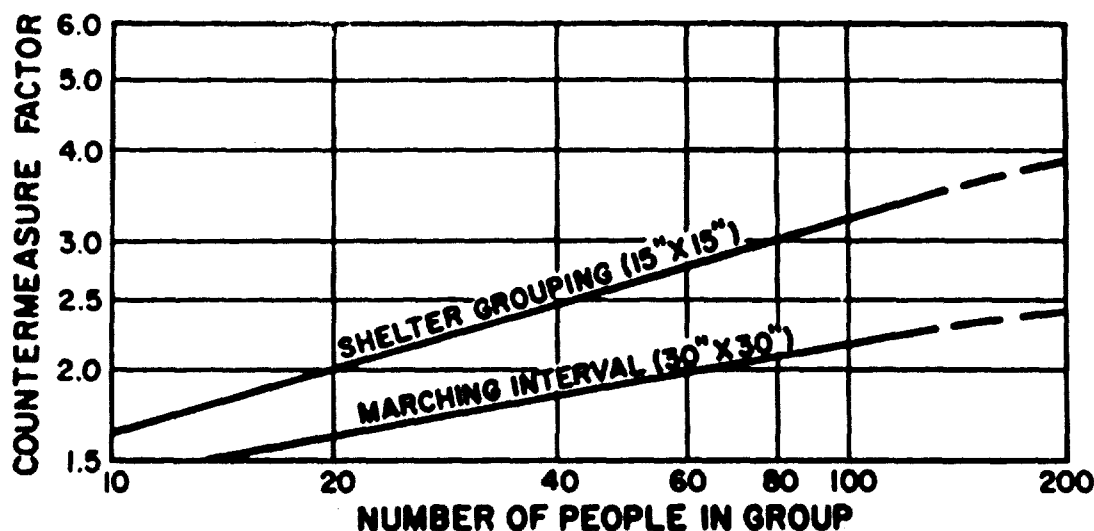


Fig. A-1. Countermeasure Factor As a Function of the Number of People in a Group (assumes random movement to equalize dose)

ground-level shelters and the results are not necessarily applicable to other shelter configurations.<sup>2</sup>

Another special use of dose equalization is shelter rotation; i.e., occupants are periodically moved between two adjacent shelters of differing dose rates in order to equalize their doses. Shelter rotation would probably be limited to dose rate differentials of greater than 25 percent because a dose differential of less than 20 percent is probably not significant. Rotation between shelters could be scheduled at frequent intervals to insure the uniformity of equalization but since the major concern is to equalize dose

<sup>2</sup> The effectiveness noted is attributable to an increased density (from closely packed bodies) in the horizontal plane which reduces the horizontal (wall) contribution. The effect on vertical (floor and roof) contributions has not been investigated but would undoubtedly be less significant since the vertical density is not correspondingly increased by group shielding techniques. The question of whether a reduction in dose to one part of the body as opposed to another has any effect in reducing "injury" is essentially one aspect of the problem of "whole-body" vs "partial-body" exposure. This problem has not been resolved or even considered in depth for any of the common exposure environments. Its consideration is not a part of this study.

over some period — say 2 weeks — a single movement would suffice.<sup>3</sup> The time at which rotation must be undertaken is shown in Fig. A-2 for two different criteria. In the upper curve the dose received by the occupants of the two shelters is equalized over a two-week period; in the lower curve the dose is equalized at the time of the peak ERD. As shown, the time of rotation is dependent upon the effective time of arrival of fallout; however, it is independent of the PFs of the two shelters (Appendix E).

Example: For an effective time of arrival of  $H + 4$  hr and dose equalization based on time of peak ERD the time of rotation would be  $H + 28$  hr.

It is essential to note that shelter rotation considers only the equalization of the dose received by the occupants of two different shelters; it says nothing about the absolute dose which is received and if applied without consideration of the dose estimation techniques described in the following sections, could result in gross, albeit equalized, overexposure.

## EXPOSURE SCHEDULING

Exposure scheduling considers the time after burst at which an operation is scheduled (reflecting the effect of radioactive decay of the fallout) and the time required to perform the operation. Because of the rapid decay of radioactive fallout at early times, operations involving exposure to high-intensity fields are delayed for at least 24 hr after attack, if possible. By the end of the first week after attack, radiation intensity has decreased sufficiently that the time of initiating an action is no longer critical, although it certainly remains an important parameter in most cases.

The time devoted to an operation is also an important consideration in exposure scheduling. At very early times after attack, the time period may have to be limited to a few minutes, whereas after the first week, the period may be unlimited. The relationships of earliest entry time (i.e., when the task can be started), the time required for the task, and reference intensity are shown in Fig. A-3. Figure A-3a illustrates, for an unprotected man, the

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<sup>3</sup> As explained in Appendix E, Fig. E-2, more frequent rotation necessitates that the first movement occur at an earlier time — often inconvenient or impractical.

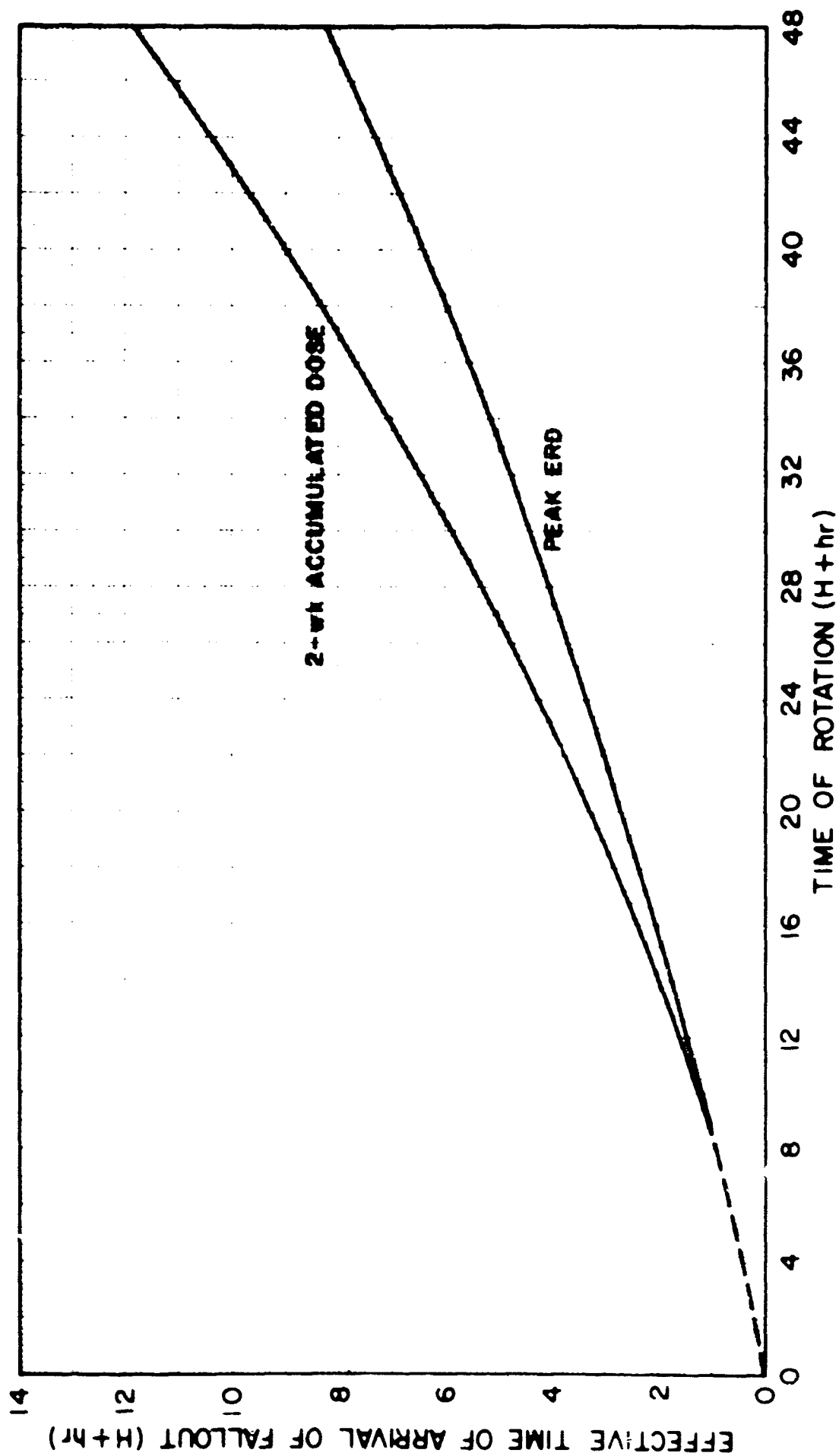


Fig. A-2. Time of Rotation Between Two Shelters As a Function of Effective Time of Arrival of Fallout

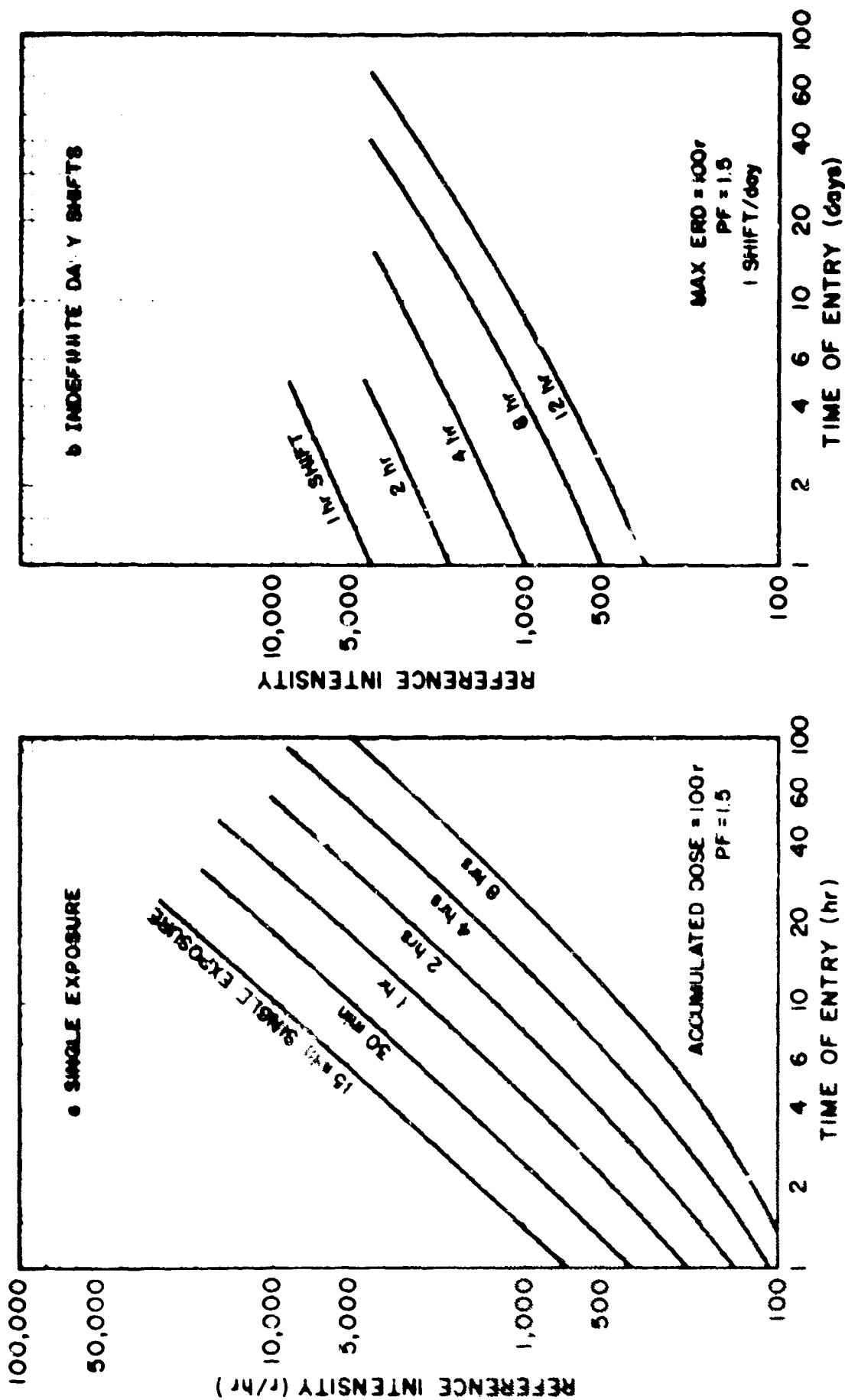


Fig. A-3. Earliest Entry Time for Single and Continual Exposure

earliest time at which a single task can be done. For example, if a man has to shut off a gas valve, requiring a 15-min exposure, in a 4,000-r/hr radiation field, he can do so at  $H + 5$  hr while receiving 100 r (ERD). Figure A-3b illustrates, for an unprotected man, the earliest time at which a daily schedule (e.g., 4 hr per day indefinitely) can be initiated. In practice, short shifts might be used at early times after attack and longer shifts at later times.

Exposure scheduling becomes more complex as the number of radiological environments increases and the time spent in each environment changes. These more intricate exposure scheduling problems are discussed under dose assessment (Appendix B).



## Appendix B

### DOSE ASSESSMENT PROCEDURES

This appendix presents estimates of the effective time of arrival of fallout (the earliest time at which exposure can begin) and methods for calculating dose, with and without a biological recovery factor, for one-, two-, and three-stage environments. ERD (equivalent residual dose), which includes a biological recovery factor, provides more accurate estimates of injury,<sup>\*</sup> but because of the complexity of the computations, is generally restricted to preattack planning use. Accumulated dose, although a less accurate estimate of injury (even when adjusted to account for biological recovery), is easily calculated and compares directly with measured dose (from dosimeters), and consequently is most useful for postattack implementation. A comparison of these two methods of calculating dose is given below (p. B-3), followed by detailed procedures on the assessment of ERD and accumulated dose.

#### EFFECTIVE TIME OF ARRIVAL OF FALLOUT

Earlier work (Ref. 1) defined the mode of fallout deposition in a form that permitted dose during fallout to be predicted. This model is still generally applicable, except that some improvements have been introduced in the course of this investigation. However, for the present study, in which total dose over an extended period is of concern, a simpler concept, effective time of arrival of fallout, was deemed adequate and was accordingly adopted. The effective time of arrival is the time at which half of the total dose during the period of fallout deposition has been received. Figure B-1, which is calculated from results from the Miller model (Ref. 21), lists for three fission yields the effective time of arrival as a function of downwind distance (for an effective wind speed of 15 mph). Although an effective arrival time of  $H + 1$  hr is commonly used, values ranging from 1/2 hr to 24 hr or more are possible. The effective time of arrival at close-in points where stem fallout is significant is not well defined but might be somewhat less than 1/2 hr.

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<sup>1</sup> Radiological injury as defined in Ref. 13 is "a collective term to describe all effects on human beings. It includes every grade of severity from the undetectable to the fatal."

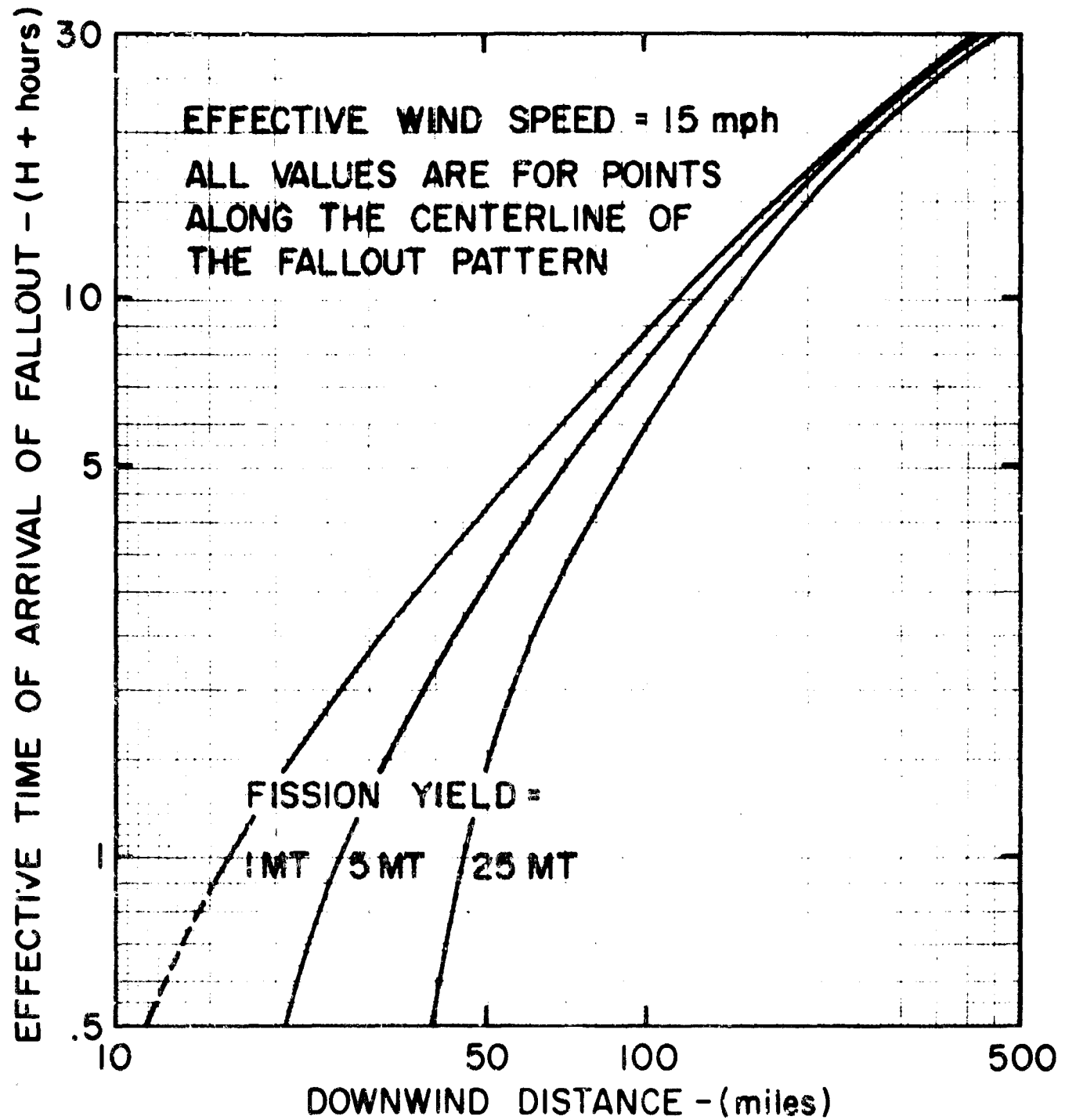


Fig. B-1. Effective Time of Arrival of Fallout vs Downwind Distance for Three Weapon Yields

In an actual fallout situation the effective time of arrival can be roughly estimated for arrival times of less than 10 hr as: effective time of arrival = 1.5 times observed time of arrival of first fallout.

#### COMPARISON OF ERD AND ACCUMULATED DOSE

The accumulated dose model used is the familiar:

$$D_A = \frac{I_0}{P} \int_{t_1}^{t_2} t^{-n} dt \quad (B.1)$$

where

$D_A$  = total accumulated dose (r)

$I_0$  = reference intensity (r/hr at 1 hr)

$P$  = PF

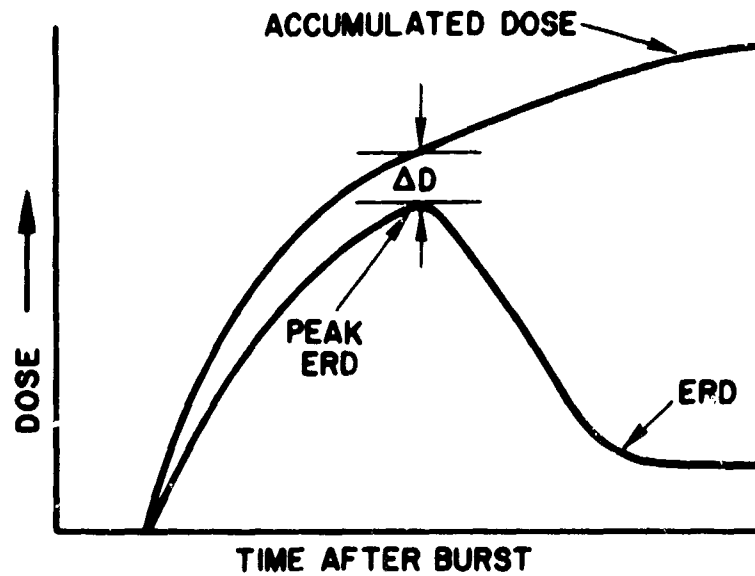
$t$  = time after burst (hr)

$n \approx 1.2$

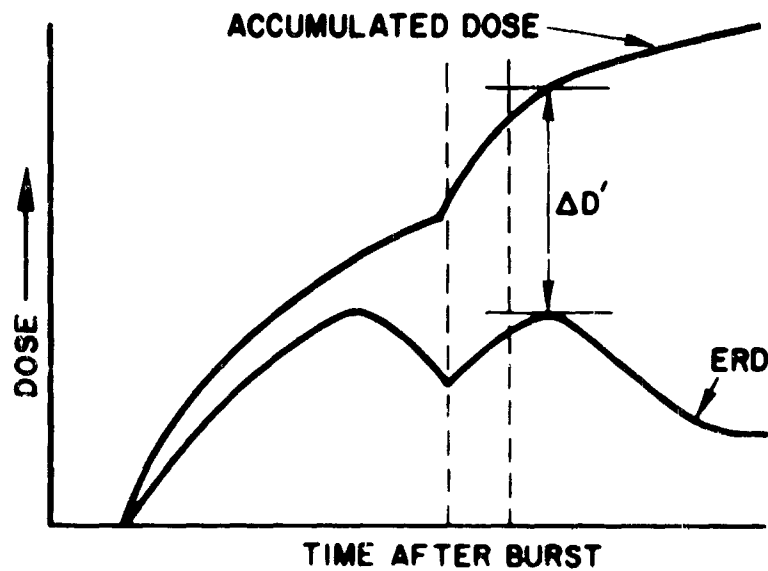
Other decay schemes have not been considered in this report; previous work (Ref. 1) has shown the  $t^{-1.2}$  relationship to be sufficiently accurate for dose calculations for the first four months after detonation. Also, significant deviations most often occur at very early times, when direct dose measurements are available, and thus need not affect dose predictions at later times. However, the decay scheme favored by Miller (Ref. 25) is compatible with the planning procedures of this report.

The ERD model used herein (Ref. 22) considers 10 percent of the injury attributed to dose as irreparable, while the body repairs the remaining 90 percent at the rate of 2.5 percent per day, starting from the time of initial exposure.<sup>2</sup> A typical ERD curve is compared with an accumulated dose curve below:

<sup>2</sup> Many studies have been made of various ERD models and the use of such models in calculating dose. A recent report by RTI (Ref. 23) gives an excellent exposition of the mathematical basis for computations. The use of a computer printout for ERD assessment is discussed in a recent OEP publication (Ref. 24).



The significant difference between the two models is shown as  $\Delta D$ , i.e., the difference between peak ERD and accumulated dose at the same time. The value of  $\Delta D$  can be estimated for simple cases, but for more complex situations, estimates become quite unreliable; an example of such a case is shown below:



Now  $\Delta D'$ , because it occurs after the first ERD peak, represents an appreciable deviation from accumulated dose. In comparison then, the use of ERD presents the planner with a more accurate measurement of injury and, in comparison to accumulated dose, will allow more latitude in operating in radiological environments. However, ERD is difficult to calculate and the units are incompatible with instrument output. Accumulated dose can be calculated by hand methods and the units (roentgens) are identical with instrument output. Hence, both models have been investigated on the basis that ERD should be used, as much as possible, for preattack planning, while accumulated dose is best adapted for postattack implementation.

### Computation of ERD

ERD computations, using a modified computer program based on Ref. 22, were made for various operational situations. The simplest case is for a one-stage environment, i.e., continuous exposure to a uniform fallout field from initial entry to final exit. Figure B-2 is a plot of the Dose Rate Multiplier (DRM), an index of the rate of decay of the radioactive fallout versus time (t) after attack. ERD is calculated as follows:

$$ERD = \frac{I_0}{P} DRM$$

where

$I_0$  = reference intensity (r/hr)

$P$  = PF

### Example 1

Enter a radiation field at  $H + 10$  days and leave at  $H + 20$  days. What is the ERD if the reference dose rate ( $I_0/P$ ) is 500 r/hr?

Solution: from Fig. B-2, following the curve originating at 10 days yields a DRM value of 0.18 at 20 days. Thus,

$$ERD = 500(0.18) = 90 \text{ r}$$

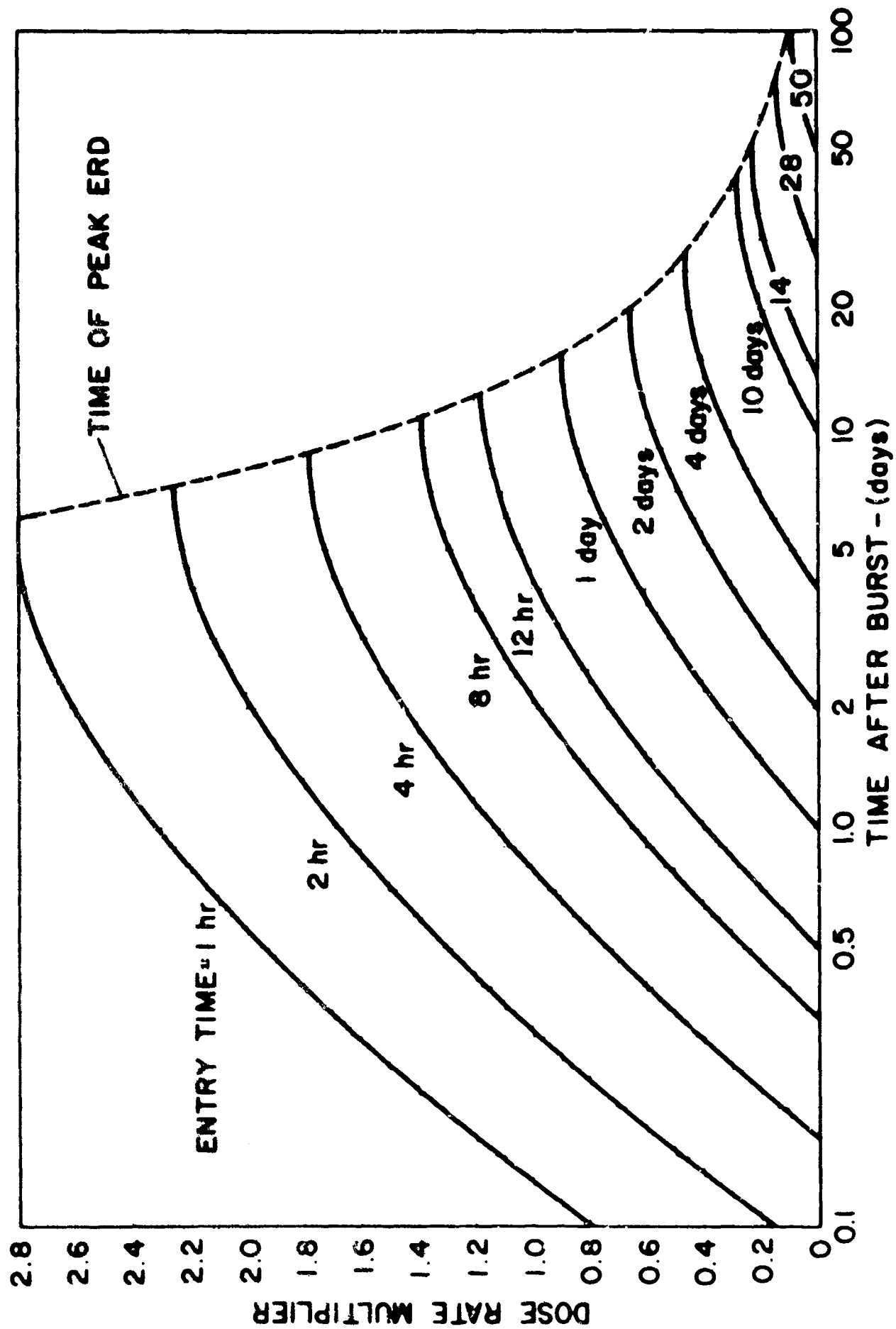


Fig. B-2. Dose Rate Multiplier Curves and Time of Peak ERD

Although Fig. B-2 can be used to estimate dose for short-term occupancy (as shown above), the more probable case for a one-stage environment is the occupation for an indefinite period of a lightly contaminated area by previously unexposed personnel. In this instance the curve in Fig. B-2 labeled "Time of Peak ERD"<sup>3</sup> would apply.

### Example 2

What is ERD for personnel, previously unexposed to radiation, entering a radiation field,  $I_0 = 600$ , at  $H + 2$  days for an extended period, assuming a PF of 2?

Solution: From Fig. B-2, follow the curve originating at  $H + 2$  days to its intersection at Time of Peak ERD, finding that  $DRM = 0.64$ . Then,

$$ERD = \frac{600}{2} 0.64 = 192 \text{ r}$$

Peripheral countermeasures are most commonly used under more complex situations, in which two- or three-stage environments are encountered. The simplest case of a two-stage environment is local reoccupancy, i.e., persons in a shelter from time of attack emerge from the shelter to adjacent living and/or working areas. Figure B-3 provides the basis for calculating ERD for a two-stage environment. Variables in Fig. B-3 are:

$E'$  = peak ERD

$t_x$  = time of emergence ( $H +$  days)

$r_1$  = reference dose rate inside shelter (r/hr)

$r_3$  = reference dose rate after emergence (r/hr)

The only nonvariable is the effective time of arrival of fallout, which, for Fig. B-3, is  $H + 1$  hr. (A similar curve for an effective arrival time of 4 hr is given in Fig. B-4.) An example of using Fig. B-3 is given below:

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<sup>3</sup> Peak ERD represents the maximum dose which can be received for occupancy of this duration or longer.

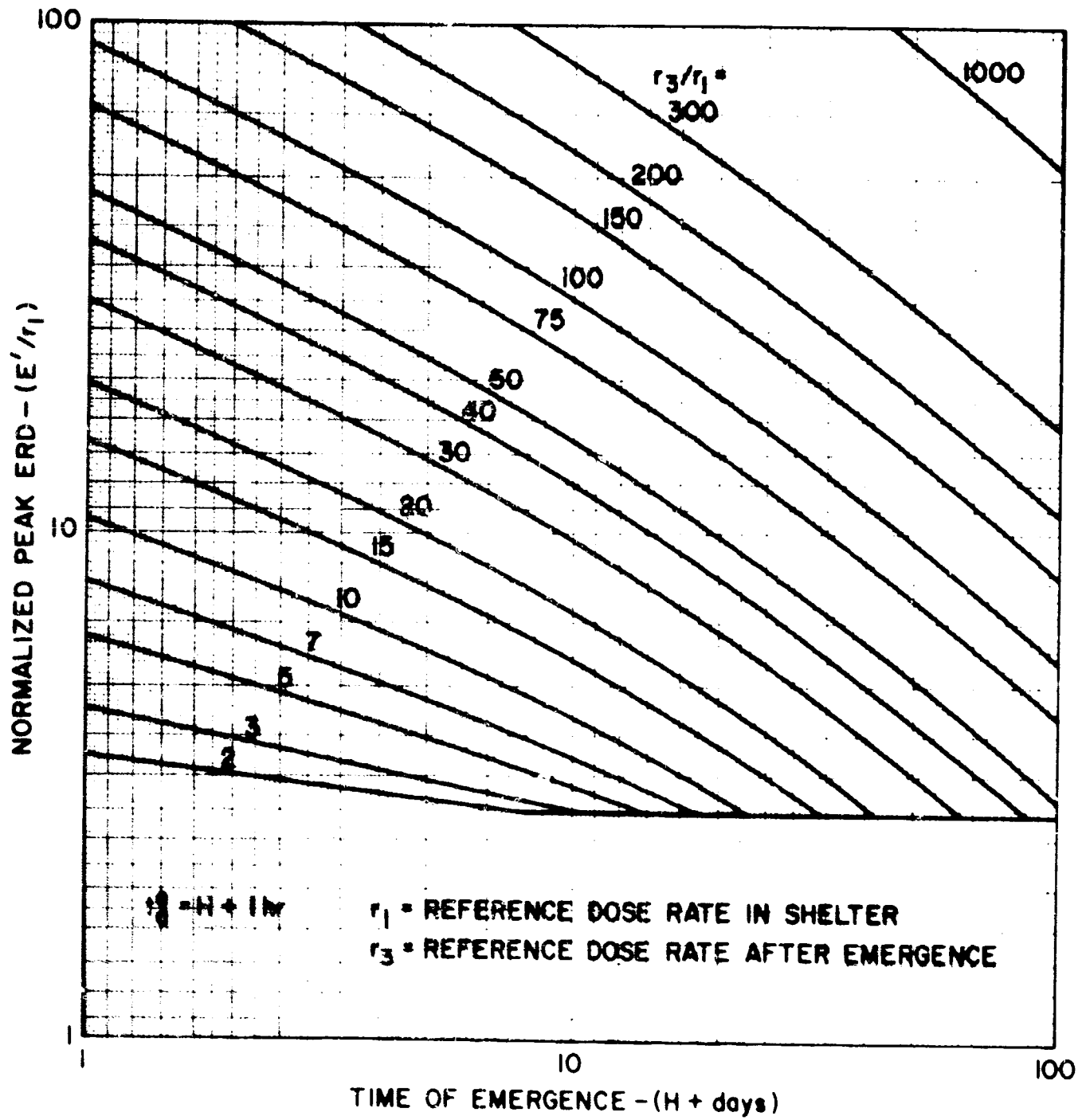


Fig. B-3. Peak ERD vs Time of Emergence for Two-Stage Movement and Effective Time of Arrival of 1 hr



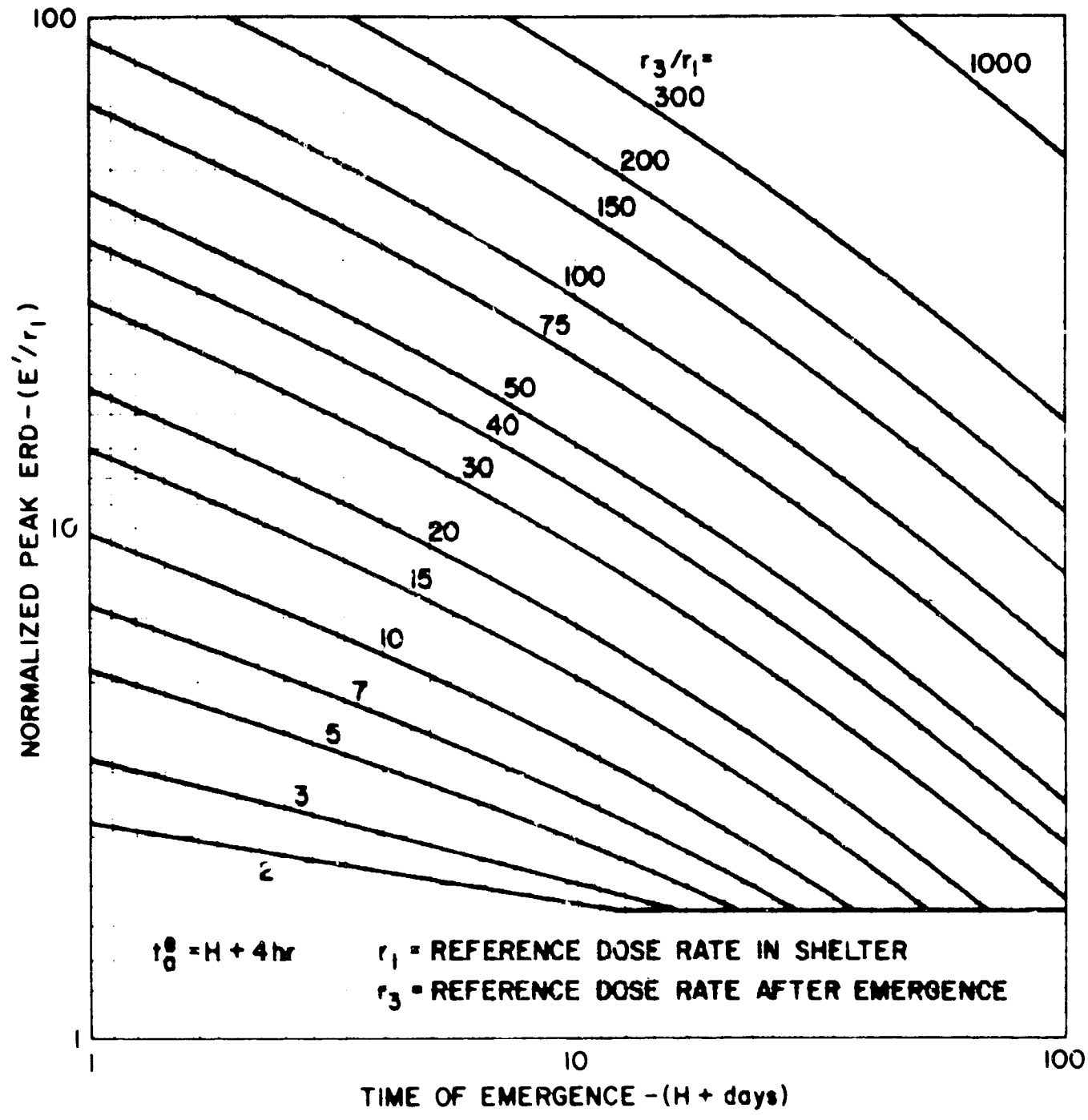


Fig. B-4. Peak ERD vs Time of Emergence for Two-Stage Movement and Effective Time of Arrival of 4 hr

$$r_1 = \frac{I_0}{P_1} = \frac{2,000}{100} = 20 \text{ r/hr}$$

$$r_3 = \frac{I_0}{P_3} = \frac{2,000}{2} = 1,000 \text{ r/hr}$$

Find ERD for emergence at  $H + 10$  days.

Solution: Determine the intersection of  $t_x = 10$  days with the curve  $r_3/r_1 = 1,000/20 = 50$ . A line is now extended horizontally from this point, intersecting at  $E'/r_1 = 15$ , i.e.,

$$E' = 15 r_1$$

Since

$$r_1 = 20 \text{ r/hr}$$

$$E' = 15(20) = 300 \text{ r}$$

In this example, then, movement at 10 days would result in overexposure and could be inadvisable.

A two-stage environment which involves movement from the shelter through open terrain to a "free" (i.e., uncontaminated) zone, presents a more complex radiological problem and hence is considered as a special case of the three-stage environment discussed below.

Although considerable effort was devoted to the estimation of ERD for a three-stage environment (i.e., from shelter through open terrain to a secondary site), it does not appear to be amenable to an easy solution. Figure B-5 is an example of the relationship between the dose rates in the three radiological environments for a given operational condition. In this figure, four parameters — effective time of arrival of fallout, permissible dose, time of emergence (go-time), and travel time — have been specified and, in effect, limit the usefulness of the figure to one specific operational condition.

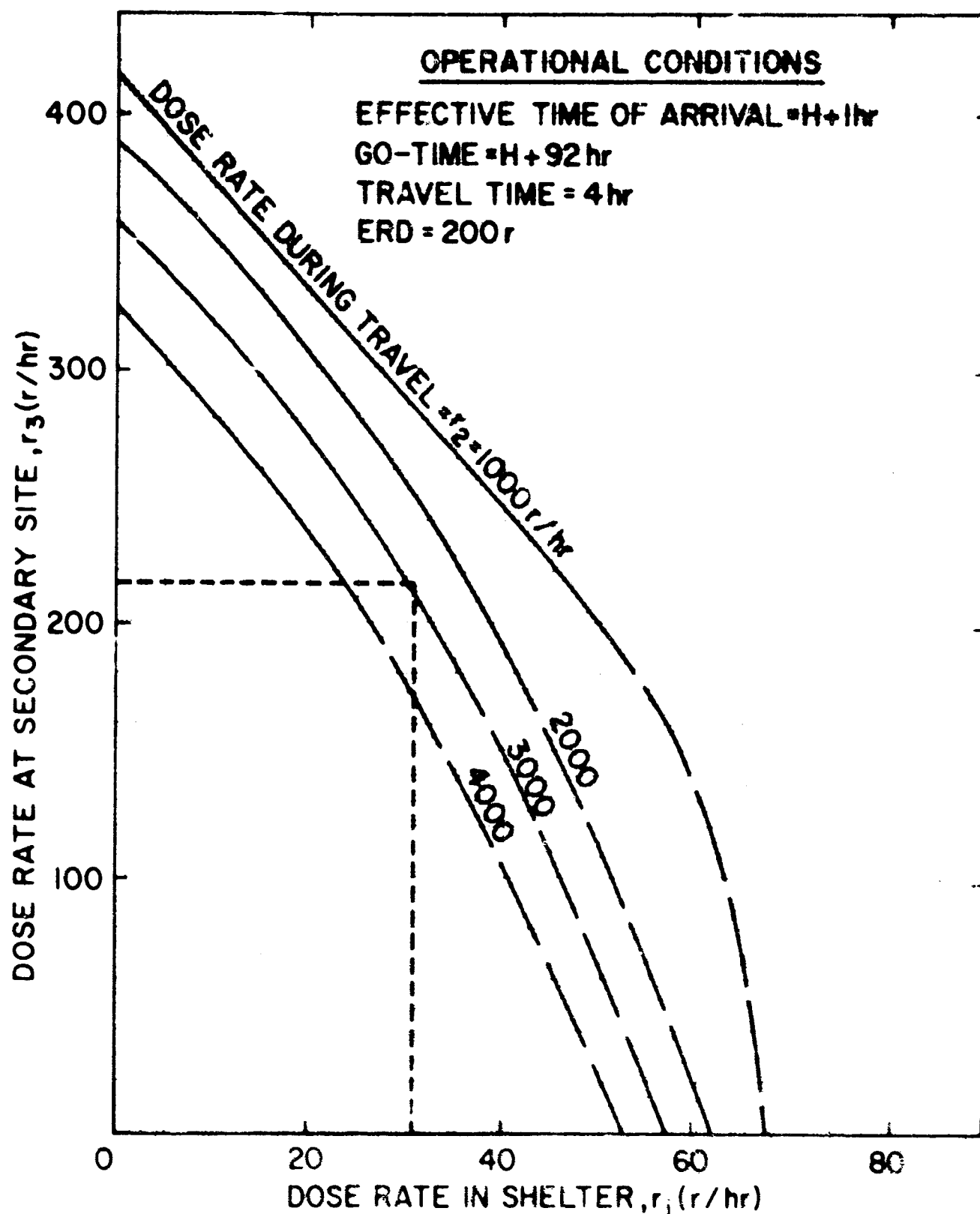


Fig. B-5. Relationship of Reference Dose Rates in Three Radiological Environments for a Given Operational Condition

Despite this limitation, Fig. B-5 does illustrate the relationship of the reference dose rates for three sequential radiological environments. In the example shown by a dashed line, a dose rate in the shelter of 3 r/hr would limit the reference dose rate during travel to 3,000 r/hr if the reference dose rate at the secondary site were 210 r/hr. Figure B-5 also illustrates the general requirement that dose rates between three environments must be balanced, or else one environment will overwhelm and consume all the available dose. For example, if the dose rate at the secondary site is 400 r/hr, the dose rate during travel would have to be less than 1,500 r/hr, and the dose rate in the shelter would have to approach zero.

The use of a series of figures similar to Fig. B-5 was considered for preattack planning of three-stage environments, but it soon became obvious that too many discrete cases would be involved. However, since a relatively simple general solution is available for accumulated dose (see next section), a correlation between ERD and accumulated dose was sought, so that the simpler solution could be used, and the accuracy of the ERD concept still retained. A number of operational and radiological situations were compared for the two procedures, and the correlations shown in Table B-1 were derived.

Table B-1

## CONVERSION OF ACCUMULATED DOSE TO GIVE AN ERD OF 200 r

Go-Time (H + days)	Accumulated Dose Equivalent to 200 r (ERD)				Dose Received In
	$r_3/r_1 = 1$	$r_3/r_1 = 3$	$r_3/r_1 = 10$	$r_3/r_1 \geq 30$	
< 1	200	200	200	200	10 days
1 - 3	210	220	235	250	15 days
3 - 8	220	235	265	285	25 days
8 - 14	235	265	310	310	35 days

Notes:  $r_3/r_1$  = reference dose rate at secondary site divided by reference dose rate in shelter

Allowable accumulated dose values are accurate to  $\pm 20$  percent.

Table B-1 uses go-time and the ratio  $r_3/r_1$  as inputs; travel time and reference dose rate during travel can safely be ignored within the accuracy of the values given ( $\pm 20$  percent). The output from Table B-1 is the allowable accumulated dose, equivalent to 200 r (ERD), received in the specified period. Because Table B-1 correlates accumulated dose with peak ERD for a number of conditions, the results are much more accurate than the general case, i.e., 230 r in two weeks or 290 r in one month. Table B-1 would be used as follows (input is from the example shown in Fig. B-5 and accumulated dose,  $D_A$ , is calculated using Fig. B-8):

<u>Period</u>	<u>Reference Dose Rate (r/hr)</u>	<u>Time In (hr)</u>	<u>Time Out (hr)</u>	<u>Accumulated Dose (r)</u>
1	30	1	92	89
2	3,000	92	96	54
3	215	96	600 <sup>†</sup>	<u>129</u>
				272

<sup>†</sup> The period in which dose is received, 25 days, is obtained from Table B-1 for the case of  $t_x = 3$  to 8 days.

From Table B-1, for  $t_x = 3$  to 8 days and  $r_3/r_1 = 215/30 = 7.2$ , an interpolated value of 255 r is obtained.

$$\text{Error} = \left( \frac{255 - 272}{272} \right) 100 = -6 \text{ percent}$$

#### Computations of Accumulated Dose

The basis for computing accumulated dose ( $D_A$ ) is the equation:

$$D_A = 5 \frac{I_0}{P} (t_1^{-0.2} - t_2^{-0.2}) \quad (\text{B.2})$$

Equation (B.2), derived from Eq. (B.1), can be solved using conventional mathematical techniques or by the use of nomographs, but for most purposes a DRM curve, shown in Fig. B-6, is sufficiently accurate and is convenient to use.<sup>4</sup> This curve is used in Eq. (B.2) by

$$\begin{aligned} D_A &= I_0 (\text{DRM at } t_2 - \text{DRM at } t_1) \\ &= I_0 (\Delta \text{DRM}) \end{aligned} \quad (\text{B.3})$$

For a single-stage environment, Eq. (B.3) could be used as follows:

$$I_0 = 100 \text{ r/hr}$$

$$t_1 = H + 10 \text{ hr}$$

$$t_2 = H + 20 \text{ hr}$$

$$D_A = 100(2.25 - 1.84) = 41 \text{ r}$$

For very short periods, the  $\Delta \text{DRM}$  value can be obtained from the nomograph shown in Fig. B-7. At the sacrifice of some accuracy, the range of Fig. B-7 can be extended by introducing a common factor into the elapsed time and  $\Delta \text{DRM}$  scales. For example, an elapsed time of 4 hr ( $2 \times 2$  hr) for a time of emergence of 30 hr would result in a  $\Delta \text{DRM}$  of  $2 \times 0.035 = 0.070$ .

Accumulated dose for two- and three-stage environments can also be solved using the DRM; nomographs (Ref. 1) and a slide rule (Ref. 26) have also recently been developed for that purpose. However, for those more complex situations, none of these procedures allows a ready comparison, within a given dose constraint, of the various radiological and operational parameters involved.

<sup>4</sup> Another advantage of using DRM curves is that other modes of fallout decay can be readily introduced into dose calculations; for example, DRM curves for the decay scheme favored by Miller are given in Ref. 25.

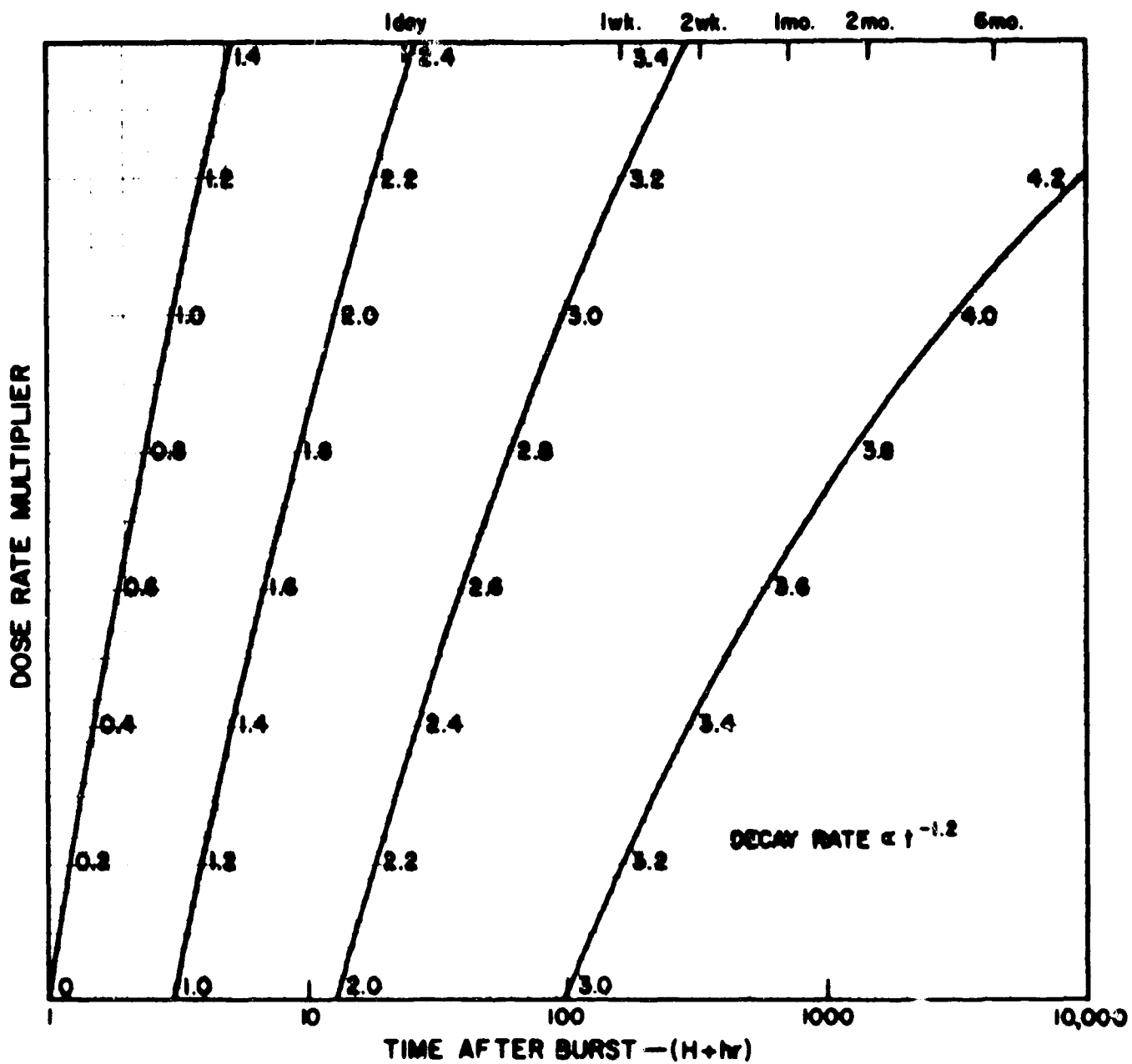


Fig. B-6. Dose Rate Multiplier Curve for  $t^{-1.2}$

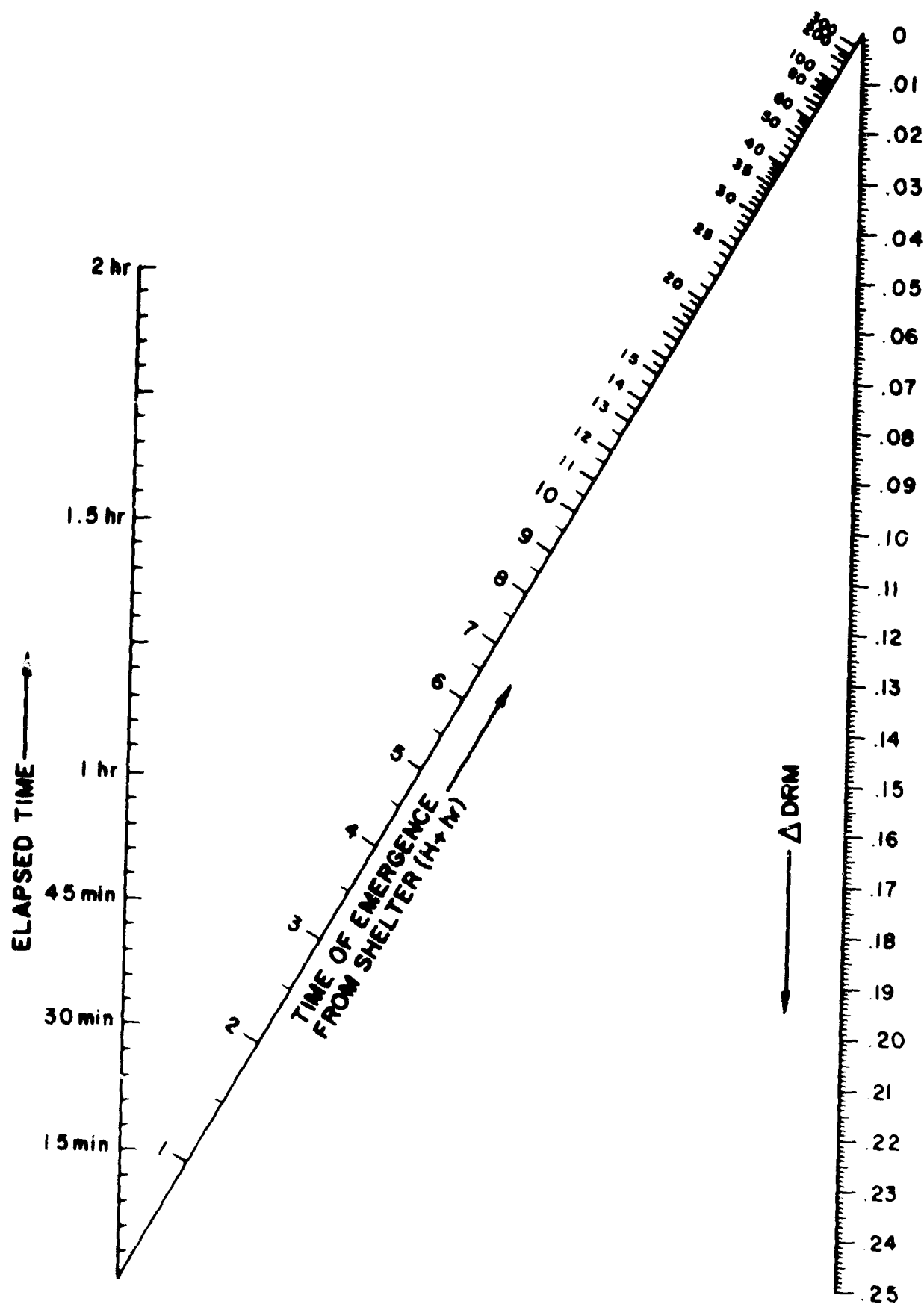


Fig. B-7. Nomograph for Determining DRM for Short Periods



Accordingly, a nomograph (Fig. B-8) was developed which accounts for all pertinent parameters in a three-stage environment.

The parameters, and their symbols, are:

$$r_1 = \frac{I_o}{P_1} = \text{reference dose rate in shelter (r/hr)}$$

$$r_2 = \frac{I'_o}{P_2} = \text{reference dose rate during travel (r/hr)}$$

$$r_3 = \frac{I''_o}{P_3} = \text{reference dose rate at secondary site (r/hr)}$$

$$D_A^* = \text{allowable accumulated dose (r)}$$

$$\Delta \text{DRM} = \text{increment of the DRM for the period spent in the environment}$$

To use Fig. B-8, the steps followed are:

- (1) Establish values for known factors.
- (2) Determine  $\Delta \text{DRM}$  values from Figs. B-6 or B-7.
- (3) Determine unknown factors from Fig. B-8.

#### Example 1

Given: Effective time of arrival of fallout =  $H + 4$  hr

Leave shelter at  $H + 72$  hr

Travel time = 2 hr

Arrive at secondary site at  $H + 74$  hr

Remain at secondary site until  $H + 2$  weeks

$$r_1 = \frac{I_o}{P_1} = \frac{5,000}{250} = 20 \text{ r/hr}$$

$$r_2 = \frac{I'_o}{P_2} = \frac{3,000}{3} = 1,000 \text{ r/hr}$$

$$\text{Allowable dose in first two weeks} = D^* = 100 \text{ r}$$

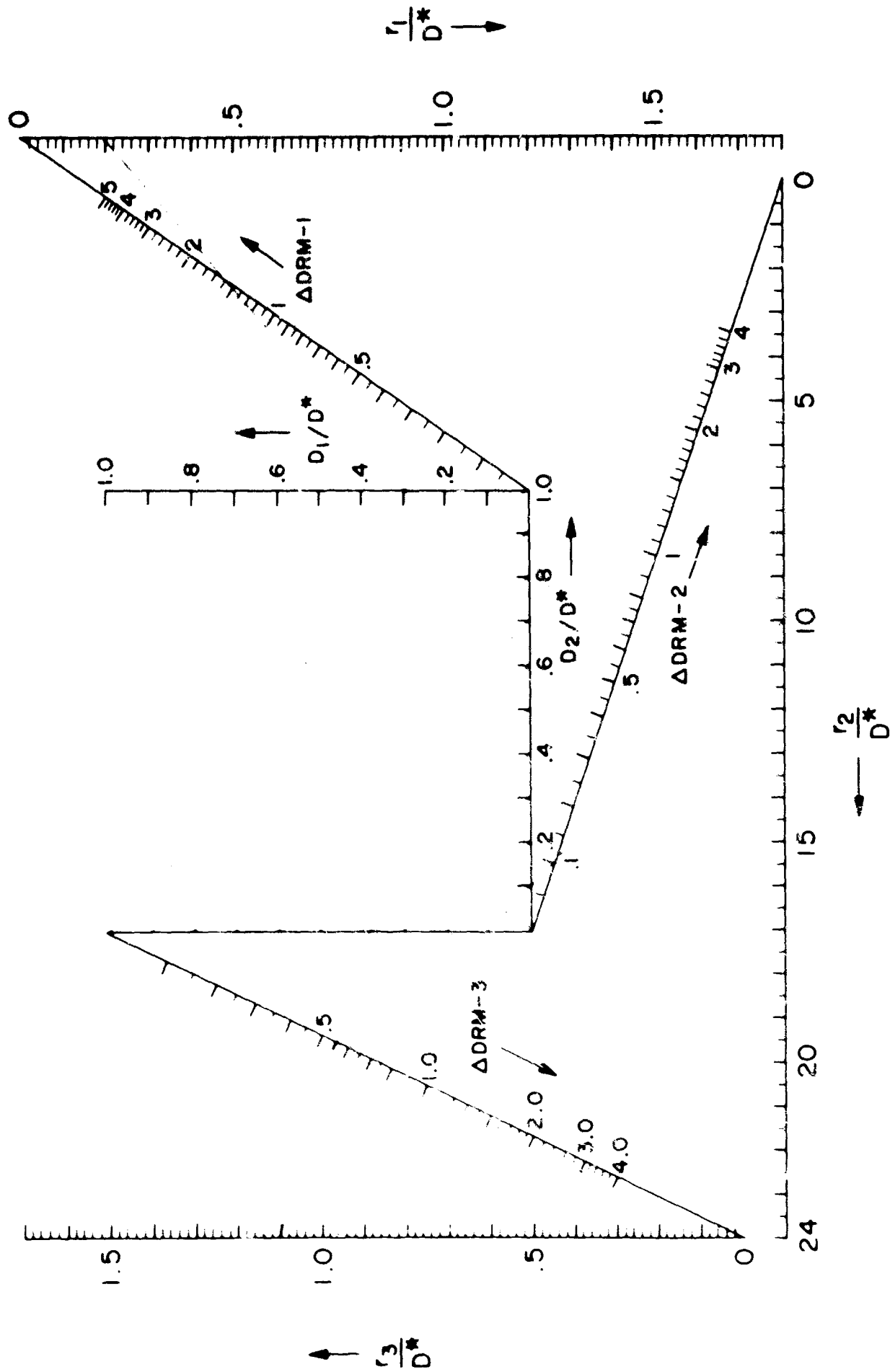


Fig. B-8. Nomograph of Relationship of Dose Received in Three Radiological Environments

**Find:** The maximum permissible dose rate at the secondary site.

**Solution:**

**(a) Dose Received While in Shelter**

From Fig. B-6, determine difference between DRM values at  $H + 4$  hr and  $H + 72$  hr. Thus:

<u>Time</u>	<u>DRM</u>
$H + 72$	2.67
$H + 4$	<u>1.08</u>
$\Delta \text{DRM-1} = 1.59$	

Since  $r_1 = 20$  and  $D^* = 100$ ,

$$\frac{r_1}{D^*} = \frac{20}{100} = 0.2$$

From Fig. B-8, using the above values, a line can be drawn between  $r_1/D^*$  and  $\Delta \text{DRM-1}$  as shown. It is found that  $D_1/D^* = 0.29$ , i.e., 29 percent of the total dose will be received during shelter occupancy.<sup>5</sup>

**(b) Dose Received During Travel**

Because of the short time interval, Fig. B-7 is used to determine  $\Delta \text{DRM-2}$ . Locating the travel time at 2 hr and time of emergence at  $H + 72$  hr and extending a straight line through these two points, one finds a  $\Delta \text{DRM-2}$  of 0.011. Since  $r_2 = 1,000$ ,

$$\frac{r_2}{D^*} = \frac{1,000}{100} = 10$$

With these values and Fig. B-8 a line is drawn, as shown, to  $D_2/D^* = 0.10$ .

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<sup>5</sup> Observed dose can be used when available. If this example had been prepared at  $H + 48$  hr, the value of  $D_1$  would have been

$$D_1 = \text{observed dose to 48 hr} + \text{calculated dose from 48 to 72 hr}$$

(c) Permissible Dose While Occupying the Secondary Site

Since it has been found that  $D_1 = 29$  percent and  $D_2 = 10$  percent of the total permissible dose,  $D^*$ , then  $D_3$  must represent the remaining 61 percent. This is shown in Fig. B-8 by extending lines from  $D_1/D^*$  and  $D_2/D^*$  to their intersection at  $D_3/D^* = 0.61$ .

To determine the permissible dose rate at the secondary site, extend the line from  $D_3/D^*$  to the reference line and from this intersection through  $\Delta\text{DRM}-3 = 0.57$  (i.e.,  $3.25 - 2.68$ ), finding that:

$$\frac{r_3}{D^*} = 111$$

since

$$D^* = 100, \quad r_3 = 111$$

i.e., the limiting dose rate for the secondary site is 111 r/hr.<sup>6</sup>

Example 2

Given: Effective time of arrival of fallout =  $H + 4$  hr

Leave shelter at  $H + 24$  hr

Travel time = 2 hr

Remain at secondary site until  $H + 2$  weeks

Allowable dose in first 2 weeks = 100 r

Find: The relationship of dose rates for the three time periods given.

Procedure. Construct a graph which relates all possible dose rates.

(1) Find  $\Delta\text{DRM}$  values for the three time periods:

(a) From Fig. B-6,  $\Delta\text{DRM}-1 = 2.09 - 1.08 = 1.01$

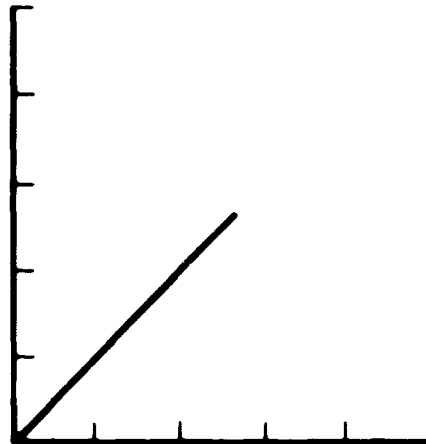
<sup>6</sup> A correction for biological recovery could now be introduced by using Table B-1. Knowing that  $r_3/r_1 = 111/20 = 5.5$  and  $t \approx 3$  days, one can find an interpolated value (for an ERD of 100 r) of  $\approx 120$  r received in 15 days. These new values can now be introduced and the value of  $r_3$  recalculated.

(b) From Fig. B-7,  $\Delta\text{DRM}-2 = 0.044$

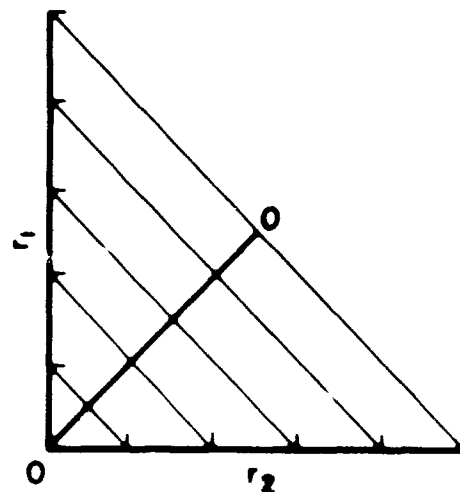
(c) From Fig. B-6,  $\Delta\text{DRM}-3 = 3.25 - 2.13 = 1.12$

(2) Construct, on graph paper, a graph as follows:

Step I. Prepare vertical and horizontal axes with 10 divisions (for simplicity only 5 divisions are shown) and draw a 45-deg line through the origin, as shown.



Step II. Connect identical points on the vertical and horizontal scales. Add dose rate designations and zero marks. NOTE: The zero mark for  $r_3$  does not coincide with the other zero marks.

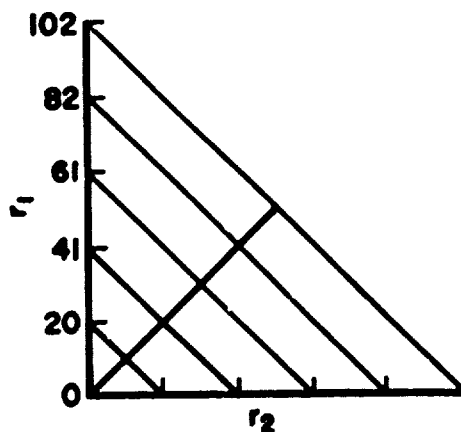


(3) Maximum dose rates are determined by assuming that the entire dose is received in only one time period, i.e.,  $D/D^* = 1.0$ .

(a) Maximum dose rate in shelter: using Fig. B-8 and the values  $D_1/D^* = 1.0$  and  $\Delta\text{DRM}-1 = 1.01$ , we find that  $r_1/D^* = 1.02$ .

Since  $D^* = 100$  r, the maximum dose rate in shelter is 102 r/hr at 1 hr.

This maximum dose rate can then be placed on the graph, as shown. Further, the intervals between 102 and 0 can be determined ( $102/5 = 20.4$  r/hr per interval).



- (b) Similarly, the maximum dose rate for travel is determined from Fig. B-8, using

$$D_2/D^* = 1.0$$

and

$$\Delta \text{DRM-2} = 0.044$$

so that

$$r_2/D^* = 22.5$$

and

$$r_2 = 2,250 \text{ r/hr}$$

- (c) Similarly, the maximum dose rate at the secondary site can be found to be

$$r_3 = 90 \text{ r/hr}$$

Figure B-9 can be used to determine acceptable dose rate combinations within the stated time constraints. For example, if  $r_1 = 61$  and  $r_3 = 18$ , then  $r_2$  cannot be greater than 450. If these latter limits are too stringent, and movement at  $H + 24$  hr is necessary, measures might be undertaken to improve the PF of the shelter. If  $r_1$  were reduced to 41 and  $r_3$  remained at 18, then a value of 900 for  $r_2$  would be acceptable. Such a graph allows, in short, a rapid analysis of the importance of the three environments - shelter,

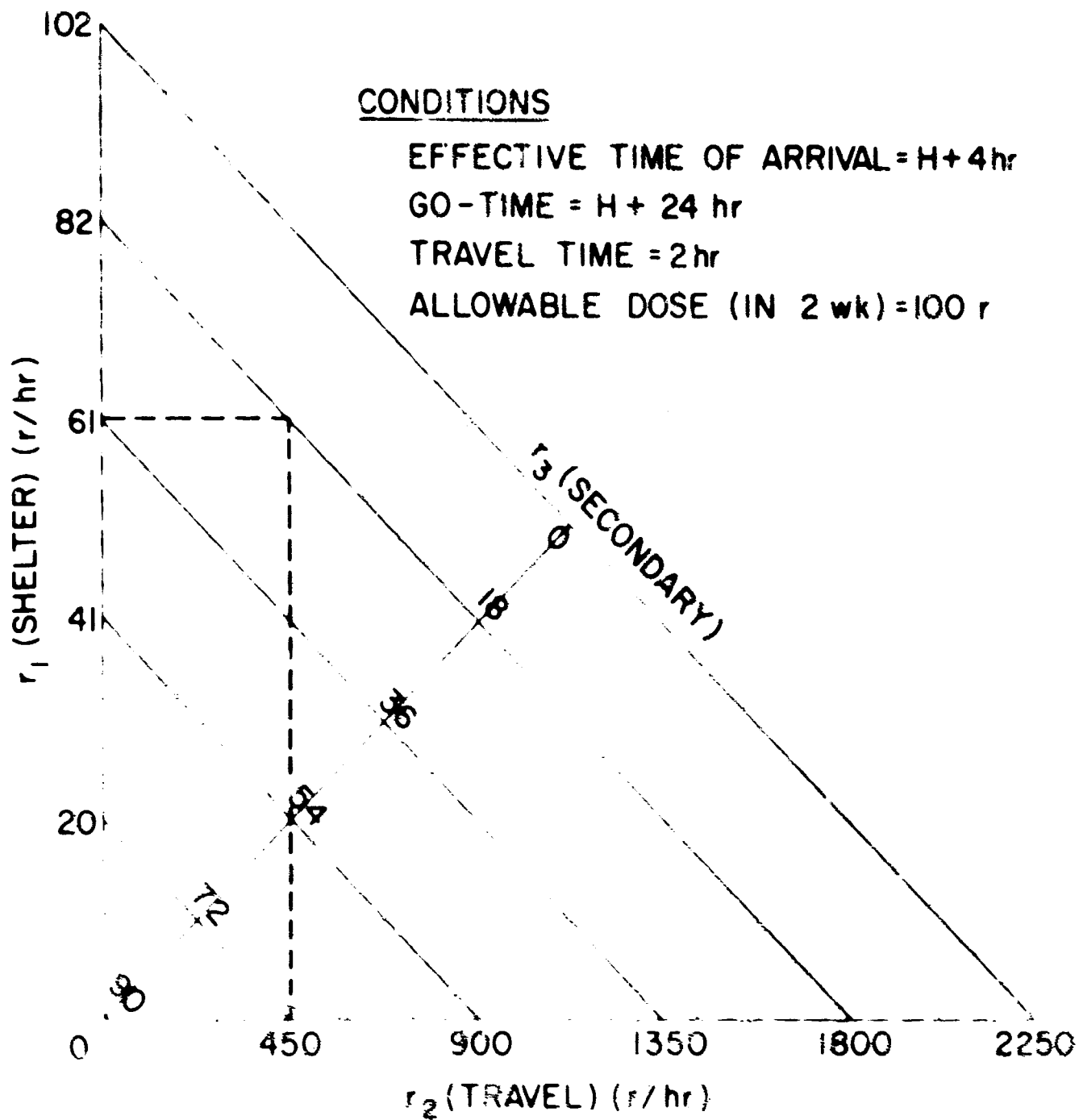


Fig. B-9. Relationship of Three Dose Rates for a Given Operational Condition

travel, and secondary site - for a given time-phasing. If other time-phasing is of interest, e.g., movement at  $H + 48$  hr, a similar graph can rapidly be constructed and dose rates can be evaluated and compared.



Appendix C  
PILOT STUDY OF TWO COMMUNITIES

Two disparate communities, Oakland, California and Montgomery County, Maryland, were studied to (1) determine problems in the proposed use of peripheral countermeasures and (2) assess the usefulness of the proposed planning guides and decision procedures in a realistic situation. It has been shown that peripheral countermeasures are technically feasible and operationally practical, but still untested were possible management constraints imposed by the nature of the community and its civil defense organization.

The major concerns were to determine if the community could provide the necessary support for peripheral countermeasures and how this support could be channeled through the civil defense organization. The assessment of management practicality for a community was conducted by using facilities available to the EOC to prepare inventories of necessary resources (shelter and refuge spaces, food stocks, transportation, etc.) for selected areas in the community.<sup>1</sup> The results of these studies were then used to estimate the effort required for preattack planning and the practicality of integrating such preattack planning into current practices

The two communities studied had, except for an above-average civil defense organization, little in common. Oakland, a metropolitan city of 370,000 covering an area of 53 square miles, is a part of the San Francisco complex. The civil defense organization, located in a temporary EOC, is directly under the Police Department but receives heavy support from the Fire Department. In time of emergency, the city manager assumes leadership and directs operations from the EOC. Oakland is located in Alameda County, which includes 13 incorporated cities distributed throughout its 733 - square-mile area, and which has a permanent EOC about 10 miles from Oakland.

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<sup>1</sup> The inventory was conducted by URS personnel.

In common with many municipalities, Oakland is a "core" city, and for this reason, most of its 166 stocked shelters (all in PF category 4-8), representing 166,000 spaces, are located in the central business district. Although Oakland has a shelter deficiency, the deficit could be sharply reduced by including spaces in PF categories 2 and 3 and by expending money on upgrading available spaces in PF categories 4-8.

Presently communications between the EOC and shelters is limited to commercial telephone (and then only to the shelter building), but plans call for a radio link (using the two-way radios from the city's taxicab fleet) and ultimately, a telephone link using the Police-Fire Department underground system. The Fire Department has a well-developed dispersal plan designed to save personnel and equipment. Although mutual aid agreements are in effect with neighboring communities, it is assumed that during a major disaster such aid would be negligible.

Montgomery County, located just north of Washington, D.C., encompasses in its 493 square miles urban, suburban, and rural area. Most of the population is located in unincorporated, contiguous communities in the lower (southern portion) county, where shelters are scattered in 6 major and 32 minor complexes. The upper county, primarily rural, has few public shelters; home basements constitute the majority of the available shelter space. The actual distribution is:

<u>Location</u>	<u>Resident Population</u>	<u>Public Shelter Spaces<sup>2</sup></u>	<u>Home Basement Spaces</u>
Lower county	378,381	390,757	-
Upper county	33,700	1,887	33,766

<sup>2</sup> On the basis of 6.9 ft<sup>2</sup> per occupant

The EOC for Montgomery County, located at the county office building, incorporates police and fire dispatching functions as well as civil defense functions. The civil defense organization, staffed by county employees, is under the county manager. Although civil defense districts have been established (by means of election district boundaries), they have little operational significance. Most of the nearly 300 shelters in the lower county fall logically into one of the shelter complexes which report through a single channel, possibly the local police precinct, to the EOC.

Montgomery County has an excellent civil defense plan for shelter assignment and for mobilizing the capabilities of the county government, but postattack problems have not been studied in depth

The survey of the two communities was conducted as follows:

- (1) An initiation conference was held with the active head of the civil defense organization during which information was exchanged on the goals of the study and on the civil defense structure of the community.
- (2) Information on shelter, alternate shelter, and refuge spaces (including PF values) was obtained for selected areas of the community by inspection of the Phase I and II NFSS printout, stored in the EOC, and the current files on stocked shelters.
- (3) Informational sources for resources were investigated; these included:
  - (a) Chamber of Commerce (useful for selected categories such as 25 largest manufacturers, employers, etc., or for total employment).
  - (b) Census data (useful for a given product or service for number of workers, number of employers, gross sales, etc).
  - (c) Business license division (of no use in Montgomery County and of limited use in Oakland).
  - (d) Telephone directories listings, whether by category—as in the classified directory or by address, as in the street-by-street directory, were not complete and gave no indication of size of the resource).
  - (e) City directories. These were not available for Oakland but were available for some parts of Montgomery County. The street-by-street listing was current and included, with a minimum of errors,

all categories of resources by type, but not quantity. A listing by category was also included and appeared to be relatively complete.

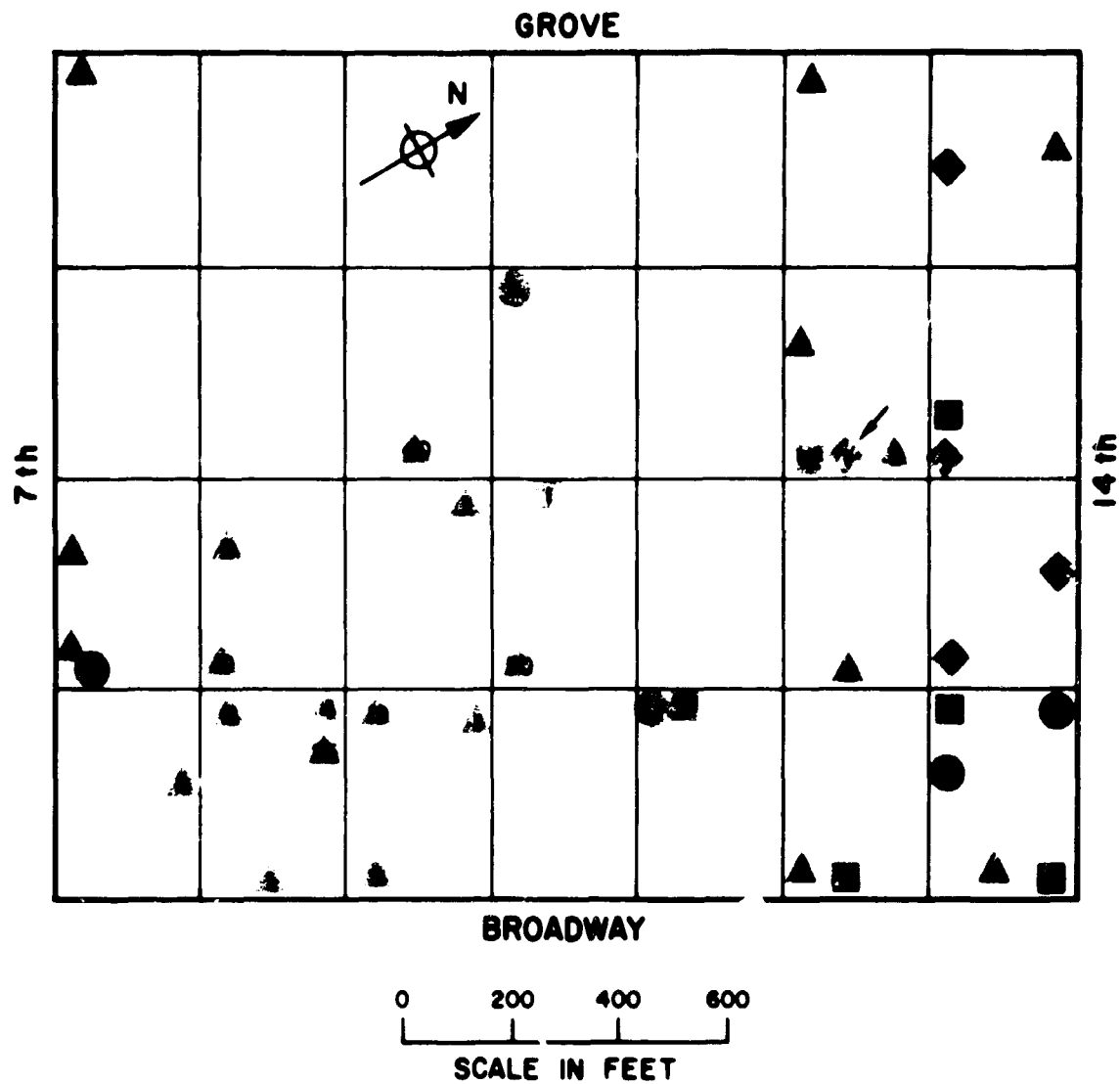
- (f) Directory services. A list of all retail grocers, bakeries, and confectioners was obtained for Oakland and Bethesda, Maryland. The grocers—296 in Oakland and 8 in Bethesda—were graded according to gross worth and listed by address. However, the indication of size was not found to be meaningful and several important grocery stores were not identified.
- (g) Fire Department. In Oakland, the 29 fire stations could provide current information on commercial property size and use in a street-by-street listing. In Montgomery County, which has approximately 15 fire departments, many of which are volunteer, no such files were maintained.
- (h) Fire marshal. In Oakland, a central file which duplicated those of each of the fire departments, but were less current, were found. A central file of inspection reports was available in Montgomery County and could provide information on resource availability.

Through the cooperation of the civil defense organization in the two communities and the assistance of the governmental units noted above, sufficiently detailed data for an assessment of the management practicality of peripheral countermeasures was obtained. This assessment served as a basis for several of the preceeding sections. For illustrative purposes, a few specific examples of the data collected will be presented in Appendix D.

Figures C-1—C-4 show for four areas, the distribution of shelter and refuge spaces and food supplies.<sup>3</sup> These data vary considerably in reliability but are believed to be sufficiently accurate for planning purposes. The shelter and alternate shelter spaces were obtained from current files in the EOC and refuge spaces from the Phase I NFSS printout. Food resources for Oakland were derived from Fire Department and fire marshal files and, for Montgomery County, from the Polk City Directory. Food sources were estimated as small, medium, or large, using either an estimate of floor area occupied or a "drive-by" inspection. The correlation

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<sup>3</sup> Food stocks, although a secondary consideration for implementation of peripheral countermeasures, have been used for illustrative purposes.



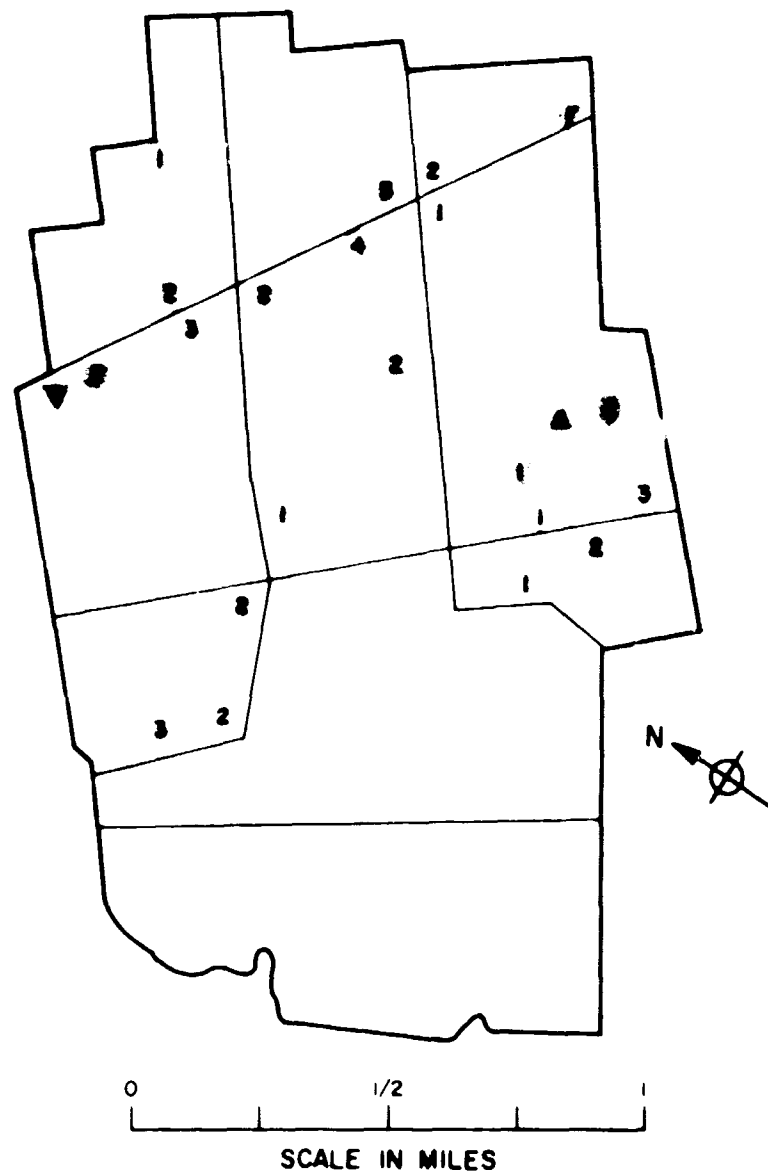
<u>ITEM</u>	<u>UNIT</u>	<u>SYMBOL *</u>
SHELTER	500 SPACES	◆
REFUGE	500 SPACES	■
RETAIL GROCERS & RESTAURANTS	1000 man-days OF FOOD	▲
ALTERNATE SHELTER	500 SPACES	●

\*DIGITS INSIDE SYMBOLS INDICATE NUMBER OF UNITS

NOTES

DAYTIME POPULATION - 8050  
 NIGHTTIME POPULATION - 4900  
 STOCKED SHELTER SPACES - 2573  
 ALTERNATE SPACES - 3500  
 REFUGE SPACES - 11,000  
 ESTIMATED TOTAL FOOD STOCKS - 240,000 man-days

Fig. C-1. Shelter and Resource Distribution in SL 70, Oakland, California  
 (Fringe of Central Business District)



LEGEND		
ITEM	UNIT	SYMBOL*
SHELTER	500 SPACES	
RESTAURANTS	1000 man-days OF FOOD	
RETAIL FOOD STORES	10,000 man-days OF FOOD	
FOOD MANUFACTURERS & DISTRIBUTORS	100,000 man-days OF FOOD	
SERVICE STATIONS	10,000 gal GASOLINE	

\* DIGIT INSIDE SYMBOLS INDICATES NUMBER OF UNITS

#### NOTES

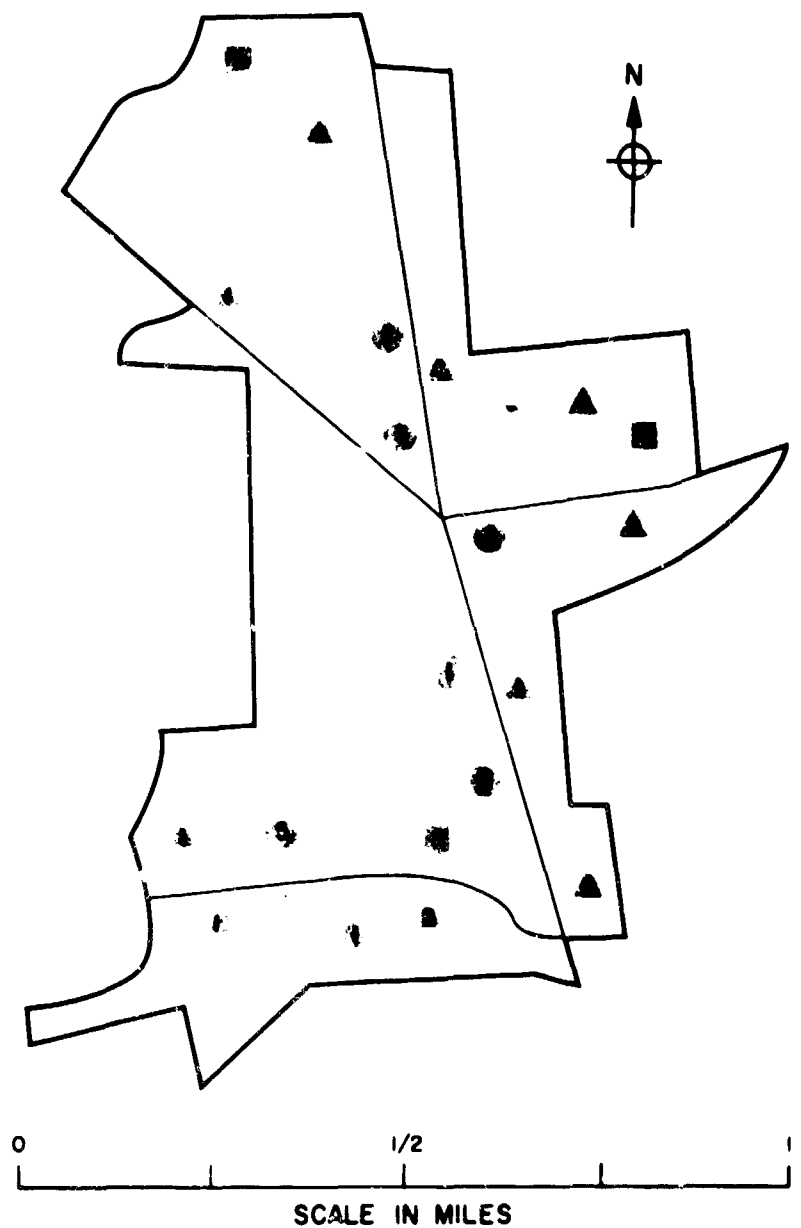
DAYTIME POPULATION - 12,569

STOCKED SHELTER SPACES - 3038

OTHER SPACES - 0

ESTIMATED TOTAL FOOD STOCKS - 750,000 man-days

Fig. C-2. Shelter and Resource Distribution in SL 128, Oakland, California (Industrial-Residential)



LEGEND		
ITEM	UNIT	SYMBOL*
SHELTER	500 SPACES	▲
REFUGE	500 SPACES	■
RETAIL GROCERS & RESTAURANTS	10,000 man-days OF FOOD	●

\*DIGIT INSIDE SYMBOLS INDICATES NUMBER OF UNITS

#### NOTES

RESIDENT POPULATION - 6779

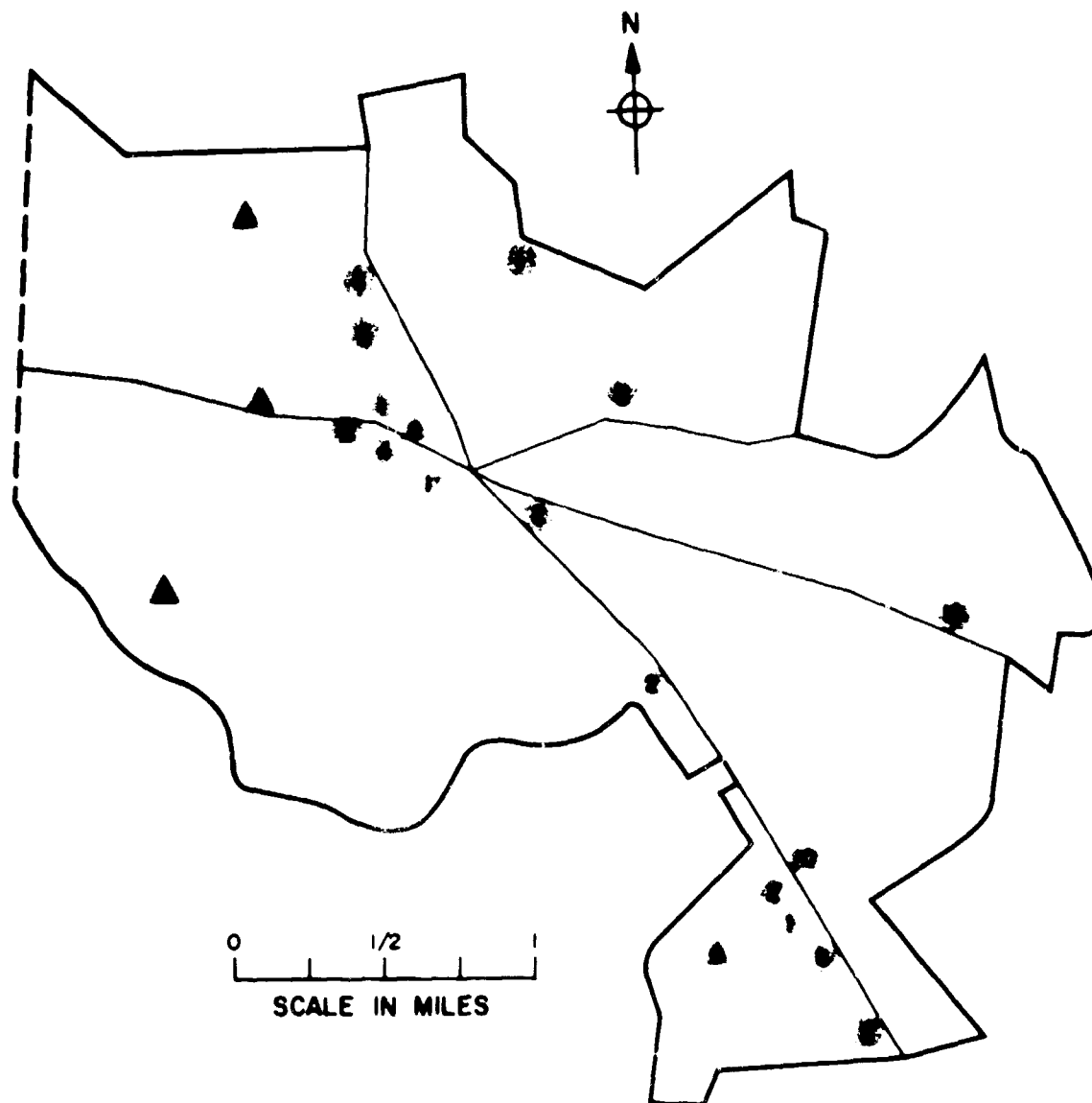
NIGHTTIME POPULATION - 14,000

STOCKED SHELTER SPACES - 9744

REFUGE SPACES - 4850

ESTIMATED TOTAL FOOD STORES - 150,000 man-days

Fig. C-3. Shelter and Resource Distribution in SL 23, Bethesda, Maryland  
(Suburban Residential-Business)



<u>ITEM</u>	<u>UNIT</u>	<u>SYMBOL*</u>
SHELTER	500 SPACES	
REFUGE	500 SPACES	
RETAIL GROCERS & RESTAURANTS	10,000 man-days OF FOOD	

\* DIGITS INSIDE SYMBOLS INDICATE NUMBER OF UNITS

#### NOTES

RESIDENT POPULATION-26,090

NIGHTTIME POPULATION - 30,000

STOCKED SHELTER SPACES - 8133

REFUGE SPACES-2145

ESTIMATED TOTAL FOOD STOCKS-570,000 man-days

**Fig. C-4. Shelter and Resource Distribution in Rockville, Maryland  
(Small Suburban Community)**



used, based on an estimated cost of \$0.0005/cal, 3,000 cal/day per person, and the approximate dollar value of inventory of a grocery store (Ref. 27), is:

<u>Size</u>	<u>Man-Days of Food</u>	
	<u>Retail Grocers</u>	<u>Restaurants</u>
Small	3,000	300
Medium	15,000	1,500
Large	45,000	4,500

On the basis of these figures, the food supply for the peak population in the three areas in which only retail grocers, confectioners, bakers and restaurants were considered are:

<u>Location</u>	<u>Figure</u>	<u>Estimated Food Supply</u>
Oakland, SL 70	18	30 days
Bethesda, SL 23	20	11 days
Rockville	21	19 days

The USDA estimates that the available food stocks from retail stores will last for 15 days for Alameda County, and for 13.5 days for Montgomery County (Ref. 28).<sup>4</sup> Homes, in each case, are estimated to represent an additional 10 day food supply. If the entire food resources of the county are considered (including wholesale, manufacturing, livestock, and produce), Montgomery County has an estimated food supply of 36 days, whereas Alameda County, which has many large canneries and food producers, has estimated stocks for 150 to 197 days.

However, for an assessment of management practicality of peripheral countermeasures, the important criterion is the availability and location of food stocks in relation to shelters and refuges. This correlation for the four areas selected to represent distinct, but typical, situations, is given in Table C-1. In this Table, adequacy is based on peak population.

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<sup>4</sup> The USDA estimate is based on 2000 cal/day per person.

Table C-1  
A COMPARISON OF RESOURCES IN FOUR LOCATIONS

Figure	Location	Availability			
		Shelter Spaces	Refuge Spaces	Home Basement	Food Stocks
C-1	Fringe of central business district of large city	-	+	-	+
C-2	Industrial-residential area of large city	-	-	-	+
C-3	Small suburban community	-	+	+	+
C-4	Urban fringe-residential	+	-	-	+

+ = surplus or adequate

- = inadequate or insufficient

These selected locations reflect the general situation quite well, i.e., shelter spaces are generally in short supply, food stocks at the retail level are adequate, and refuge spaces and home basement availability is extremely variable.

The locations<sup>5</sup> and quantities shown in Figs. C-1-C-4 are, in some cases, approximate, since two or more smaller units have been grouped together. However, these approximations do not distract from the presentation of the shelter to resource distribution pattern. Figure C-1, for a standard location (SL) on the fringe of the Oakland central business district, shows a concentration of shelter and alternate shelter spaces which, in total, could handle the nighttime population but not that during the day. By using the many refuge spaces, all persons could be sheltered to some degree. However, although radiological protection might be adequate, these excess spaces could not be used for any length of time unless food and water stocks were also available. Fortunately, in this standard location two large retail grocers, several small grocers, a few restaurants, and several hot dog stands could provide adequate provisions for a number of days (especially if spoilable foods were utilized first). Water, or water substitutes, would be available from food stocks or from trapped water in buildings.

In the central business district proper, the problems change somewhat. For example, SL 74, adjacent to SL 70, has a resident population of 1292, a daytime population of 11,500 and approximately 12,000 shelter spaces, 17,000 alternate (unstocked) shelter spaces, and 13,000 refuge spaces, but a very limited food supply. In this standard location, the peak population can be housed in stocked shelters but many attractive shelter spaces may remain unused because of a food deficit, unless preattack plans make allowances for this deficit. In this case, the activity zone might have to extend radially to encompass needed food resources, but if such stocks are reserved for the shelter cluster use, the space need not remain

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<sup>5</sup> Major thoroughfares are shown to assist in orientation

undesigned or unused. With adequate preattack planning, foraging teams could, with a minimum of exposure, seek out necessary food stocks.<sup>6</sup>

Fig. C-2, for a location in south Oakland which includes some light industrial and manufacturing as well as many inexpensive single-family dwellings, has a severe shortage of shelter space but a surfeit of food supplies. The single shelter cluster is located in a large biscuit manufacturing plant, which would undoubtedly supply any and all food requirements.<sup>7</sup>

In this standard location, home basements and refuges are nonexistent, so despite the food surplus, persons would either have initially to seek shelter elsewhere or evacuate to low-intensity areas at very early times. However, the resident shelter population would have an important function in protecting the food reserves and processing facilities in the activity zone for use in the recovery period.

Figure C-3, showing a portion of Bethesda, Md., a suburban area in lower Montgomery County which includes many large apartment buildings, a few well-kept single-family dwellings and a linear, but well-defined, shopping district, indicates a well-balanced distribution of shelters and resources. The peak (nighttime) population exceeds the stocked shelter space appreciably, but by using available refuge spaces and home basements stocked from the widely scattered food stores, all of the population could be accommodated.

Figure C-4 shows the town of Rockville, Md., the county seat of Montgomery County. Rockville still maintains a degree of communal integrity despite the continuing outward growth of the suburbs from Washington, D.C. In Rockville the population far outstrips the available shelter space; the shortage is not alleviated by available refuge spaces. Because of the over-all

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<sup>6</sup> Such action might also be undertaken as a part of a crash civil defense effort.

<sup>7</sup> The management staff of the plant evinced considerable consternation when civil defense personnel attempted to stock the shelters with wafers produced by a competitor.

adequacy of shelter space in the lower county, the shelter utilization plan (Ref. 29) presupposes that unsheltered personnel in Rockville would seek shelter in one of the large shelter complexes to the south of the town. However, if attack occurred before movement to more distant shelter could be accomplished, the use of peripheral countermeasures, based on available shelter spaces, home basements and indigenous food supplies, might be a desirable solution. Other options might involve movement to shelter complexes at early times after attack or evacuation to a free zone.

An inventory of other resources of interest was conducted concurrently with the food inventory. Service stations were generally found to be widely dispersed and could provide the limited amount of gasoline required for evacuation by car. Diesel fuel supplies for heavy equipment (i.e., buses, etc) are not widely dispersed and may be difficult to locate. Further, as shown by SRI (Ref. 30), diesel fuel supplies may be seriously deficient after nuclear attack. Heavy equipment was not normally found in close proximity to shelters, although light equipment, such as fork lifts, would be available near some shelters. Building supply dealers were generally at some distance from shelter sites, although this does not hold for a small community such as Rockville. Heavy transportation, (i.e., buses and trucks) may be somewhat more available in shelters near industrialized areas but would be found only randomly in most shelter complexes or in central business districts. Drugstores were found to be scattered throughout both large and small business districts, and their stocks may be supplemented by drugs found in physicians' offices.

## Appendix D

## EXAMPLES OF USE OF PERIPHERAL COUNTERMEASURES IN SEVERAL LOCALES

## GENERAL

Several examples of the use of peripheral countermeasures, based on the pilot areas surveyed, will be given. These examples are not intended to include all possible parameters, and the input data have been "rounded off," since the intent is to illustrate a concept, rather than provide a specific plan. For the same reason, shelters and refuges have been assigned arbitrary PF values, although accurate PF values are available. Because only segments of each community have been studied, the best division of shelter and resources might not be selected, but such difficulties would be corrected if the entire community were assessed.

## EXAMPLE I: PLANNING FOR THE UTILIZATION OF REFUGE SPACES

ProblemArea

An activity zone of 14 blocks has been established which encompasses the upper half of SL 70 in Oakland (shown in Fig. C-1). This zone contains, as indicated, the following resources:

	<u>Number</u>	<u>Spaces</u>	<u>PF</u>	<u>Man-Days of Supply</u>
Shelters	3	1,500	100	—
Alternate shelters	1	500	100	—
Refuges	2	7,000	30	—
Food sources	6	—	—	56,000

The "lead" shelter manager, i.e., the coordinator of activities within the activity zone, has a trained staff and necessary guidance for the use of peripheral countermeasures and is located in the shelter marked by an arrow.

Purpose

A planning exercise, to determine how the available refuge spaces can best be utilized, is to be conducted.

Attack

Assume a 5-Mt surface burst on Hamilton AFB (27 miles distant) which produces no appreciable physical damage, but creates radioactive fallout with an effective time of arrival of 1 hr (Fig. B-1), and a reference intensity of 3,000 r/hr.

Assume that all available spaces will be filled with personnel who reach cover prior to the arrival of fallout.

Problems

- (1) Maintaining radiation dose within safe limits
- (2) Providing food for the occupants of the alternate shelter and refuges

Radiation Hazard

Dose to shelter occupants is found to be within acceptable limits:

$$r_1 = \frac{3,000 \text{ r/hr}}{100} = 30 \text{ r/hr}$$

$$\Delta\text{DRM-1} = 3.44 - 0 \text{ (for 2 weeks)}$$

so

$$D_{2 \text{ wk}} = r_1 \times \Delta\text{DRM-1} = 30 \times 3.44 = 103.2 \text{ r} \quad (\text{Fig. B-6})$$

or, from Fig. B-2,

$$\text{ERD} = 30 \times 2.82 = 84.6 \text{ r}$$

However, refuge occupants would receive a serious overdose:

$$r_1 = \frac{3,000 \text{ r/hr}}{30} = 100 \text{ r/hr}$$

$$D_{2 \text{ wk}} = 100 \times 3.44 = 344 \text{ r} \quad (\text{Fig. B-6})$$

or

$$\text{ERD} = 100 \times 2.82 = 282 \text{ r} \quad (\text{Fig. B-2})$$

Hence, measures must be taken to alleviate this potential overexposure.

### Solution

Countermeasures must be instituted very early because of the high initial accretion of dose. For example, by H + 12 hr, the dose to personnel in the refuge is:

$$\Delta_{\text{DRM-1}} = 1.96 - 0$$

(Fig. B-6)

$$D_A = 100 \times 1.96 = 196 \text{ r}$$

From Chart 4, step 5a, the recommended procedures are a combination of applied shielding and group shielding. Group shielding, implemented immediately, is preferentially used both because of the ease of implementation and because no external exposure is required.

From Fig. A-2, for a shelter grouping of greater than 200 persons, a PF multiplier of 4 is obtained. If random group shielding is maintained for 12 hr, the 2-week dose is now found to be:

$$D_{12 \text{ hr}} = \frac{3,000 \times 1.96}{30 \times 4} = 49 \text{ r}$$

$$D_{12 \text{ hr} - 2 \text{ wk}} = \frac{3,000}{30} (3.44 - 1.96) = 148 \text{ r}$$

$$D_{2 \text{ wk}} = 49 + 148 = 197 \text{ r}$$

This dose could be reduced even further by undertaking, after group shielding is ended, to improve the PF of the shelter. If, by moving furniture, partitions, etc., within the structure, a PF of 45 could be achieved within a period of 4 hr, the resultant dose would be:



$$D_{12 \text{ hr}} = 49 \text{ r}$$

$$D_{12-16 \text{ hr}} = \frac{3,000}{30} (2.12 - 1.96) = 16 \text{ r}$$

$$D_{16 \text{ hr}-2 \text{ wk}} = \frac{3,000}{45} (3.44 - 2.12) = 88 \text{ r}$$

$$D_{2 \text{ wk}} = 49 + 16 + 88 = 153 \text{ r}$$

Note that applied shielding alone will not produce the desired end. For example, if the PF had been increased to 45 by H + 4 hr, but group shielding was not used, the resultant dose would be:

$$D_{4 \text{ hr}} = \frac{3,000}{30} 1.21 = 121 \text{ r}$$

$$D_{4 \text{ hr}-2 \text{ wk}} = \frac{3,000}{45} (3.44 - 1.21) = 149 \text{ r}$$

$$D_{2 \text{ wk}} = 121 + 149 = 270 \text{ r}$$

An alternate solution would be shelter rotation (in this case the number of shelter spaces places a constraint on such action). From Fig. A-3, for an effective time of arrival of H + 1 hr, rotation at H + 8 hr is required for dose equalization in 2 weeks.

Since the occupants of the shelters and alternate shelter would require no more than 5 minutes' travel time (maximum distance is 3 blocks), the travel dose is estimated to be:

$$\frac{5}{60} \text{ hr} \times 260 \text{ r/hr}^{\dagger} = 22 \text{ r}$$

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<sup>†</sup> The dose rate at H + 8 hr for  $I_0 = 3,000 \text{ r/hr}$  (from Fig. 9.25, Ref. 31).

Dose to refuge occupants:

$$D_{8 \text{ hr}} = \frac{3,000}{30} 1.70 = 170 \text{ r}$$

$$D_{8 \text{ hr} - 2 \text{ wk}} = \frac{3,000}{100} (3.44 - 1.70) = 52 \text{ r}$$

$$D_{2 \text{ wk}} = 170 + 22 + 52 = 244 \text{ r}$$

Dose to shelter occupants:

$$D_{8 \text{ hr}} = \frac{3,000}{100} 1.70 = 51 \text{ r}$$

$$D_{8 \text{ hr} - 2 \text{ wk}} = \frac{3,000}{30} (3.44 - 1.70) = 174 \text{ r}$$

$$D_{2 \text{ wk}} = 51 + 22 + 174 = 247 \text{ r}$$

In this case, the dose has been equalized<sup>1</sup> but is still excessive. The use of group shielding, by both sets of occupants of the refuge, could have reduced the dose to acceptable levels. The maximum saving in dose would result from the use of a combination of peripheral countermeasures, e.g., group shielding, shelter rotation, and applied shielding. For this regime, refuge occupants would practice group shielding until H + 12 hr, then rotate<sup>2</sup> to the shelter. The shelter occupants would rotate to the refuges at H + 12 hr, practice group shielding for 8 hr, and then initiate applied shielding.

Dose to refuge occupants:

$$D_{12 \text{ hr}} = \frac{3,000}{(30 \times 4)} 1.96 = 49 \text{ r}$$

<sup>1</sup> Combined dose (i.e., shelter plus refuge) is increased by the amount of the travel dose, i.e.,  $103 + 344 = (247 + 244) - 44$ .

<sup>2</sup> Because of the perturbation caused by the introduction of other peripheral countermeasures, the 8-hr rotation time no longer holds.

$$D_{\text{travel}} \approx \frac{5}{60} 180 \approx 15 \text{ r}$$

$$D_{12 \text{ hr} - 2 \text{ wk}} = \frac{3,000}{100} (3.44 - 1.96) = 45 \text{ r}$$

$$D_{2 \text{ wk}} = 49 + 15 + 45 = 109 \text{ r}$$

Dose to shelter occupants:

$$D_{12 \text{ hr}} = \frac{3,000}{100} 1.96 = 59 \text{ r}$$

$$D_{12-18 \text{ hr}} = \frac{3,000}{(30 \times 4)} (2.20 - 1.96) = 6 \text{ r}$$

$$D_{18-22 \text{ hr}} = \frac{3,000}{30} (2.30 - 2.20) = 10 \text{ r}$$

$$D_{22 \text{ hr} - 2 \text{ wk}} = \frac{3,000}{45} (3.44 - 2.30) = 76 \text{ r}$$

$$D_{2 \text{ wk}} = 59 + 15 + 6 + 10 + 76 = 166 \text{ r}$$

In this case, dose is not well equalized, so a second rotation might be considered, or those with the lower dose might be assigned reconnaissance tasks requiring additional exposure.

#### Food Supplies

Food supplies within the activity zone are marginal (i.e., 56,000 man-days of food for a population of 7,500) so that, although food would not pose an immediate problem, prompt action to save perishable foods should be instituted. With one exception, food sources are within 2-1/2 blocks of the consumer so that a round trip should not require more than 30 min. Foraging trips, beginning at H + 24 hr and repeated daily thereafter (using as many persons as required) would expend less than 50 r (ERD)

per person.<sup>3</sup> Persons involved in foraging expeditions should receive preferential placement in shelters to compensate for this additional dose.

#### Preparation for Recovery

Emergence from the shelter and initiation of the recovery phase should be considered as soon as radiologically feasible. Since, in this assumed case, physical damage is absent, reoccupation of the local area is a distinct possibility. The acceptable time of emergence can be determined from Fig. B-3, for shelter occupants who have received no dose extraneous to the shelter, as follows:

Let

$$E' = 200 \text{ r}$$

$$r_1 = \frac{3,000}{100} = 30 \text{ r/hr}$$

$$\frac{E'}{r_1} = \frac{200}{30} = 6.67$$

By inspection, PF after emergence equals 2, so

$$r_3 = \frac{3,000}{2} = 1,500$$

and

$$\frac{r_3}{r_1} = \frac{1,500}{30} = 50$$

On Fig. B-3, draw a line from  $E'/r_1 = 6.67$  to  $r_3/r_1 = 50$ . From this intersection drop a line to a time of emergence = H + 36 days.

It is decided that this time of emergence is much too late, and hence the possibility of increasing the PF of the work and living areas was

<sup>3</sup> From Fig. A-3b: a 1-hr indefinite daily shift, for  $I_0 = 3,000$   $t_x = 1$  day, will produce a maximum ERD of 100 r; hence, a 1/2-hr exposure will produce an ERD of 50 r.

explored. An increase of  $P_3$  from 2 to 5 seemed feasible so that now

$$r_3 = \frac{3,000}{5} = 600$$

$$\frac{r_3}{r_1} = \frac{600}{30} = 20$$

and repeating the process, using Fig. B-3, a time of emergence of  $H + 11$  days is found. The dose to the crew doing the applied shielding, estimated to require 8 hr, is

$$D = \frac{3,000}{2} (3.34 - 3.33) = 15 \text{ r} \quad (\text{Fig. B-6})$$

Persons who had been in refuges might also be able to reoccupy the immediate area if applied shielding were used. For example, in the case quoted above in which a dose of 153 r (in a refuge with a final PF = 45) was received in 2 weeks, an allowable dose equivalent to an ERD of 200 r (from Table B-1) is 310 r in 35 days (assuming  $r_1 = 3,000/5 = 600$  so that  $r_3/r_1 = 600/66.7 = 9 \approx 10$ ).

$$D_{14-35 \text{ days}} = \frac{3,000}{5} (3.70 - 3.44) = 156 \text{ r}$$

$$D_{0-35 \text{ days}} = 153 + 156 = 309 \text{ r}$$

So movement into the immediate surroundings, after applied shielding had been used, would be a satisfactory alternative.

#### Evacuation

Although local reoccupancy would be radiologically satisfactory for many or all of the occupants of the activity zone, the possibility of evacuating to a low-background area should also be considered. Such an area was found near Livermore, a distance of 25 miles and an estimated travel time of 2 hr.

The reference dose rate at this secondary site was 100 r/hr. The average reference dose rate during travel (including vehicular shielding) was estimated to be:

$$I'_0 = \frac{(I_0 + D''_0)/2}{P_3} = \frac{(3,000 + 100)/2}{2} = 800 \text{ r/hr}$$

Dose to H + 35 days (time of peak ERD, Table B-1) is found to be:

$$D_{0-14 \text{ days}} = 153 \text{ r}$$

$$\begin{aligned} D_{\text{travel}} &= \text{travel time} \times \text{dose rate} \\ &= 2 \text{ hr} \times 0.7^\dagger \text{ r/hr} = 1.4 \text{ r} \end{aligned}$$

$$D_{14-35 \text{ days}} = 100(3.70 - 3.44) = 26 \text{ r}$$

$$D_{0-35 \text{ days}} = 153 + 1 + 26 = 180 \text{ r}$$

From a radiological viewpoint, evacuation is preferable since a very considerable dose saving over reoccupancy ( $\Delta D = 309 - 180 = 129 \text{ r}$ ) is possible.

Most of the proposed travel route to Livermore is freeway, with little probability of blockage, so that any type of vehicular travel is satisfactory. Assuming that 5,000 persons were to be evacuated, the remainder staying behind to undertake recovery efforts in the activity zone, the number of vehicles required (from Table A-1) would be approximately 500 cars or 90 buses or 50 trailer-trucks. The activity zone could provide neither buses nor trucks so that private cars were considered. As a rough estimate of the number of cars normally in the activity zone, it was assumed that street parking would provide 20 cars per block (both sides of street) which, for the 28-block-long intervals within the activity zone, provides a possible 560 cars. This total might be decreased by less than capacity parking but might be compensated for

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<sup>†</sup> The dose rate at H + 2 weeks for  $I_0 = 800 \text{ r/hr}$ ; from Fig. 9.25, Ref. 31.

by scattered parking lots and cars in home garages. However, the use of cars entails several difficulties. First, the cars must be started, which would require either a set of master keys or an expert in "hot wiring." Second, the cars could create a traffic jam while loading and conceivably while traveling. Third, some of the cars might be low on gas or otherwise inoperable. Because of these possible difficulties, the use of buses or trucks, dispatched from the EOC, seemed to offer a better solution.

## EXAMPLE II: LIFE SAVING BY USE OF EARLY EVACUATION

### Problem

#### Locale

An activity zone in Rockville, Md. (outlined in Fig. C-4) which includes one 500-man basement shelter (PF = 50), one grocery store with estimated food stocks of 20,000 man-days, and miscellaneous resources.

#### Attack

A 1-Mt weapon has been dropped on Washington, D.C., resulting in some blast damage (estimated overpressure, 2 psi) on Rockville but, because of a heavy cloud cover, no fires are noted. Fallout starts to arrive within minutes after the attack, but the prevailing wind carries the stem fallout somewhat to the east of the activity zone.

#### Operational Situation

Warning (15 min prior to attack) resulted in a rush of people to the shelter, so that by the time the shelter was closed, 2,000 persons were inside. The ventilation problem was severe, and it was recognized that a portion of the shelter population would have to be moved out without delay. Possible actions considered were:

- Evacuate to shelter complexes in the lower county. However, information being broadcast indicated that more severe damage and heavier fallout had occurred in this area so that movement in that direction seemed inadvisable.

- Evacuate to home basements (PF ~ 10) in the activity zone which had sufficient capacity for the surplus shelter population.
- Evacuate to an area of low contamination in the upper county.

The second and third possibilities were further explored.

### Radiological Situation

The observed dose to shelter occupants at H + 2 hr was 12 r, the external dose rate was about 500 r/hr, indicating (from Fig. 9.25, Ref. 31) a reference dose rate of about 1,000 r/hr; the dose rate within the shelter was 5 r/hr, so that  $r_1 \approx 10$  r/hr.<sup>†</sup>

### Solution

The probable dose to the occupant of the shelter was calculated to be well within safe limits, i.e.,

$$D_{0-2 \text{ hr}} = 12 \text{ r}$$

$$D_{2 \text{ hr}-2 \text{ wk}} = 10(3.44 - 0.64) = 28 \text{ r}$$

$$D_{0-2 \text{ wk}} = 12 + 28 = 40 \text{ r}$$

Dose to personnel moving to home basements at H + 6 hr is estimated to be, for a travel time of 10 min:

$$D_{2-6 \text{ hr}} = 10(1.50 - 0.65) = 8.5 \text{ r}$$

(Fig. B-7)

$$D_{\text{travel}} = \frac{1,000}{1.5} (0.020) = 13 \text{ r}$$

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<sup>†</sup> The apparent PF of 100 for the shelter probably results from group shielding effects.



$$D_{6 \text{ hr}-10 \text{ days}} = \frac{1,000}{10} (3.33 - 1.50) = 183 \text{ r}^\dagger$$

(Fig. B-6)

$$D_{0-10 \text{ days}} = 9 + 12 + 13 + 183 = 217 \text{ r}$$

The accumulated dose exceeds the 200-r limit (from Table B-1) slightly, but such action might still be considered, especially if applied shielding could be used to improve the PF. For example, if 50 min were spent by the six to eight occupants of a basement in improving the PF from 10 to 20, the resultant dose would be:

$$D_{\text{work}} = \frac{1,000}{1.5} (0.095) = 63 \text{ r}$$

$$D_{7 \text{ hr}-10 \text{ days}} = \frac{1,000}{20} (3.33 - 1.61) = 88 \text{ r} \quad (\text{Fig. B-7})$$

$$D_{0-10 \text{ days}} = 9 + 12 + 13 + 63 + 88 = 185 \text{ r}$$

Evacuation to a reportedly uncontaminated area at a distance of 25 miles was next considered. For an estimated travel time of 2 hr (some debris present) and an estimated average reference dose rate, in the vehicle, of 400 r/hr, the estimated ERD for movement at H + 6 hr would be:

$$D_{0-6 \text{ hr}} = 12 + 9 = 21 \text{ r}$$

$$D_{\text{travel}} = 400(0.23) = 92 \text{ r} \quad (\text{Fig. B-7})$$

$$D_{\text{total}} = 21 + 92 = 113 \text{ r}$$

Evacuation seemed to be a desirable radiological option, and hence the operational practicality was assessed. From the resource inventory in the shelter, the presence of a school bus storage yard within the activity zone was determined. A reconnaissance by car verified that 12 undamaged buses were

<sup>†</sup> From Table B-1, the dose for a go-time of less than 1 day should be measured over a 10-day period.

in the yard. These buses could transport about 750 persons (Table A-1) and cars, driven by people coming to the shelter, could provide the necessary transportation for another 750 persons. A request was relayed to the EOC (after some delay in making contact) to evacuate using the school buses. The EOC, after verifying the presence of a free zone and indicating the best route to the designated point, approved the evacuation plan which was then implemented by the shelter manager.

# Appendix E

## SHELTER ROTATION: PAYOFF AND SCHEDULING

### NOTATION

$I(t)$  = dose rate at any given time  $(t)$ , after burst

$I_0$  = reference dose rate, r/hr at 1 hr

$P_A$  = protection factor of Shelter A

$P_B$  = protection factor of Shelter B

$R_A = I_0/P_A$  = reference dose rate inside shelter A

$R_B = I_0/P_B$  = reference dose rate inside shelter B

$t_a$  = effective time of arrival of fallout

$\tau$  = time of egression

$\tau_1, \tau_2, \dots, \tau_n$  = time of first egression, time of second egression, etc.

$n$  =  $n^{\text{th}}$  egression

$t_e$  = time at which dose is equalized

### INTRODUCTION

Before the decision is made as to whether two groups should exchange shelters, it is necessary to know how the difference in the shelter environments of groups A and B will affect total accumulated dose or the maximum ERD if no such rotation is made.

Without rotation, the total accumulated dose or the ERD for a member of shelter group A or B may be written in the form:

$$\text{Dose}_A = R_A \text{ DRM}_A \quad (\text{E.1})$$

$$\text{Dose}_B = R_B \text{ DRM}_B \quad (\text{E.2})$$

The Dose Rate Multipliers ( $DRM_A$  and  $DRM_B$ ) are functions of  $t_a^e$  and time after burst only, regardless of whether accumulated dose or ERD is being measured. Since shelter A and shelter B are located in the same fallout environment,

$$DRM_A = DRM_B \quad (E.3)$$

It follows that if

$$\frac{Dose_A - Dose_B}{Dose_A} = K$$

then from Eqs. (E.1) - (E.3)

$$\frac{P_B - P_A}{P_B} = K$$

That is, dose differential is a direct function of shelter PF differential. For example, a dose difference of 20 percent would result from a PF difference of 20 percent.

#### EGRESSION TIME THEORY

The dosage of two groups in different radiological situations can be equalized if the two groups exchange shelters (or environments) at given times after the burst. The problem is to calculate these times of "egression" ( $\tau$ ), given the reference dose rates in shelters A and B and the effective time of arrival of fallout. It was found that the value or values of  $\tau$  needed to equalize the accumulated dosage or ERD of the two groups depended only on the effective time of arrival of fallout and the arbitrarily given time of dose equalization and not on the reference dose rates in shelters A and B, as will be shown mathematically.

#### Single Egression

If group A and group B change places only once, the expression for the dosage for the two respective groups may be written:

$$\text{Dose}_A = R_A \text{ DRM}_1 + R_B \text{ DRM}_2 \quad (\text{E.4})$$

$$\text{Dose}_B = R_B \text{ DRM}_1 + R_A \text{ DRM}_2 \quad (\text{E.5})$$

In these equations, the dose rate multipliers are defined as:

$$\text{DRM}_1 = \int_{t_a}^{\tau} \frac{I(t)}{I_0} dt \quad (\text{E.6})$$

$$\text{DRM}_2 = \int_{\tau}^t \frac{I(t)}{I_0} dt \quad (\text{E.7})$$

It can be seen that if  $\text{DRM}_1$  and  $\text{DRM}_2$  are equalized, then Eq. (E.4) and Eq. (E.5) will be identical, and  $\text{Dose}_A$  will be equal to  $\text{Dose}_B$ .

Case I: Equalized Accumulated Dose for  $t^{-1.2}$  Decay

$$I(t) = I_0 t^{-1.2}$$

therefore,

$$\text{DRM}_1 = 5(t_a^{-0.2} - \tau^{-0.2})$$

$$\text{DRM}_2 = 5(\tau^{-0.2} - t_e^{-0.2})$$

Setting  $\text{DRM}_1$  equal to  $\text{DRM}_2$ ,

$$t_a^{-0.2} + t_e^{-0.2} = 2\tau^{-0.2}$$

On the basis of this equation, values of  $t_a$  and  $\tau$  were calculated for  $t_e = 2$  weeks, and the results plotted on Fig. A-3.

Case II: Equalized ERD Based on  $t^{-1.2}$

Equations (E.4) – (E.7) can be used for the computation of equalized ERD, if the  $I(t)$  in Eqs. (E.4) and (E.5) is taken to mean the net dose rate at any instant, or the dose rate coming in from the environment minus the biological recovery rate.

Since Eqs. (E.6) and (E.7) are extremely tedious to solve by hand for the ERD case, a complete set of DRM curves for ERD (obtained from the computer) was used to graphically find sets of values of  $t_a$ ,  $\tau$ , and  $t_e$  which satisfy the condition  $DRM_1 = DRM_2$ . In order to equalize the maximum values of ERD that occur for both groups, it was necessary to choose a  $t_e$  that would yield values of ERD for both groups that were close to the real maximum ERD in each of the two cases.

Difficulty was encountered because for given values of  $t_a$  and  $\tau$ , the maximum ERD for both groups does not necessarily occur at the same time for every set of  $R_A$  and  $R_B$  values. However, it was found that if  $t_e$  were set at the point where the DRM curve for  $\tau$  reached a maximum (see Fig. E-1), then the maximum values of ERD for the two groups could be equalized fairly well.

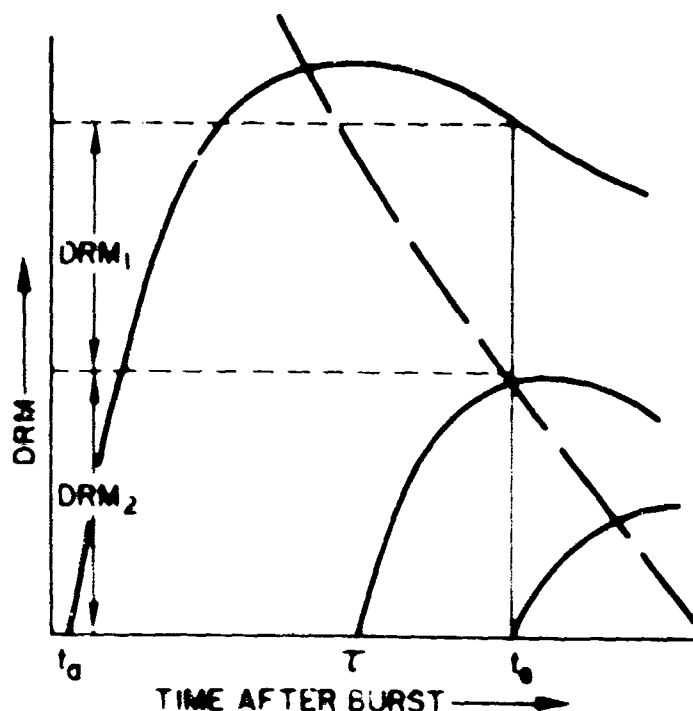


Fig. E-1. Dose Rate Multiplier Curves As a Function of Time of Egression

For extreme cases where times of egression are late and  $I_O/P_A \gg I_O/P_B$ , the "equalized" values of maximum ERD might differ by as much as 30 percent. However, as the values of  $I_O/P_A$  and  $I_O'/P_B$  approach each other, the difference between the "equalized" values decreases.

### Multiple Egression

If group A and group B exchange environments more than once, the general equation for the respective dosages would be:

$$\text{Dose}_A = R_A \text{ DRM}_1 + R_B \text{ DRM}_2 + \dots + R_A \text{ DRM}_n + R_B \text{ DRM}_{n+1}$$

$$\text{Dose}_B = R_B \text{ DRM}_1 + R_A \text{ DRM}_2 + \dots + R_B \text{ DRM}_n + R_A \text{ DRM}_{n+1}$$

Setting the coefficients of  $R_A$  equal to the coefficients of  $R_B$  equalizes  $\text{Dose}_A$  and  $\text{Dose}_B$  and results in Eq. (E.8)

$$\text{DRM}_1 + \text{DRM}_3 + \dots + \text{DRM}_n = \text{DRM}_2 + \text{DRM}_4 + \dots + \text{DRM}_{n+1} \quad (\text{E.8})$$

### Equalized Accumulated Dose Based on $t^{-1.2}$ Decay

The dose rate multipliers in Eq. (E.8) are given by.

$$\text{DRM}_1 = 5(t_a^{-0.2} - \tau_1^{-0.2})$$

$$\text{DRM}_2 = 5(\tau_1^{-0.2} - \tau_2^{-0.2})$$

$$\begin{matrix} \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \end{matrix}$$

$$\text{DRM}_{n+1} = 5(\tau_n^{-0.2} - t_e^{-0.2})$$

Substituting these expressions into Eq. (E.8) results in the generalized equation for equalized accumulated dose:

$$t_a^{-0.2} + t_e^{-0.2} = 2(\tau_1^{-0.2} - \tau_2^{-0.2} + \tau_3^{-0.2} - \dots \pm \tau_n^{-0.2})$$

On the basis of this equation, values of  $\tau_1$  and  $\tau_2$  were calculated for  $t_e = 2$  weeks,  $n = 2$ , and various values of  $t_a$ . The results are plotted in Fig. E-2.



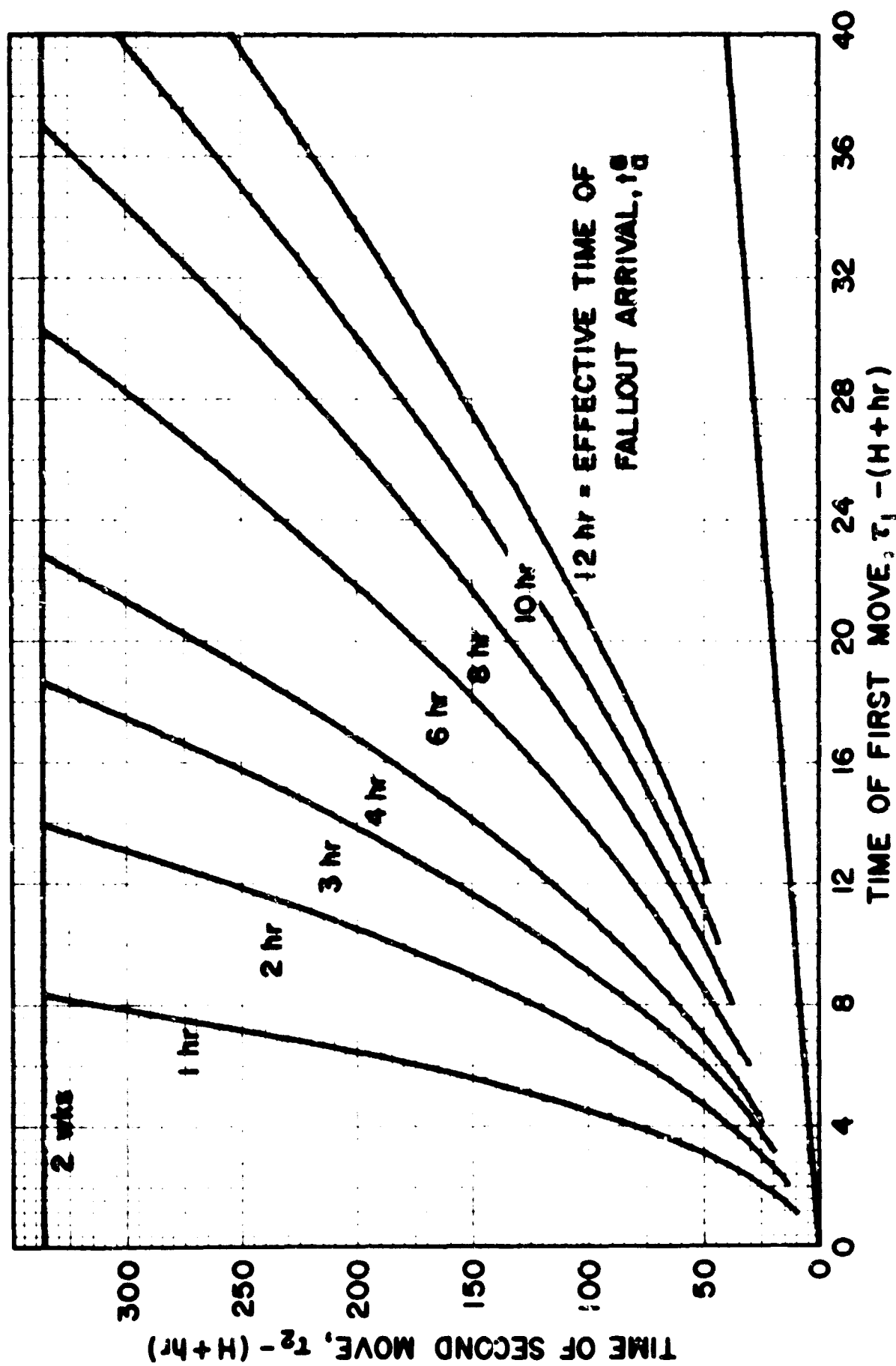


Fig. E-2. Dose Equalization for Double Egression

## Appendix F

## MODEL FOR A RESOURCE INVENTORY OF A COMMUNITY

A preattack resource inventory involves both assembling the desired information and distributing the resultant lists to the ultimate users, i.e., the EOC and the shelter managers. Although the shelter manager is the individual most concerned with the resources within his activity zone and could conceivably be assigned the responsibility for conducting the preattack inventory, it appears more desirable, because most informational sources are at a central location and include the entire community, to place the responsibility for an inventory on the local civil defense organization. Such an inventory, if conducted in one phase, would probably overtax the capabilities of the civil defense organization. However, the inventory could either be conducted by an outside consultant, or by the civil defense organization, augmented by other municipal personnel, over a period of time. Once completed, the inventory would require regular updating, but this task would be comparatively minor.

Virtually all of the information of interest for an inventory is currently available in various files and documents and merely needs to be identified and collated. Some of the principal sources of information (based upon the pilot studies of two communities) are described below for the desired input.

Alternate shelter spaces (PF < 40 but not licensed or stocked) may be listed in the files of the EOC or in the CSP (Community Shelter Plan), if available. Alternate shelter spaces, including those which have inadequate ventilation, are also listed in the Phase II printout of the NFSS (National Fallout Shelter Survey), normally filed in the EOC. Potential shelter spaces added since the last NFSS could be estimated from an inspection of the building permits file or discussions with building inspectors. A physical inspection of designated alternate shelters by the interested shelter manager (or his staff) would be advisable

to ensure that the space is "real", i.e., not occupied by hardware, such as a boiler, and also to acquaint him with the location.

Refuge spaces with a PF of from 20 to 39 can be obtained from the printout of the Phase I NFSS (normally filed at the EOC). Although these data are subject to error, since these spaces have never been inspected, they can be listed and possibly inspected at some future time. Other refuge spaces may be discovered in large storm sewer lines, utility conduits, etc. Information would be available from the respective utilities. At the local level, a "drive-through" inspection of the activity zone by the shelter manager or his staff might suggest other potential refuge spaces.

Major transportation sources, which include bus terminals, car barns, train terminals or marshaling yards, taxi garages, truck terminals, etc., could best be located and itemized through the cooperation of the respective operating companies. Since these facilities offer the capability of mass movement of personnel, they would normally fall under the cognizance of the EOC. Many civil defense organizations presently have agreements with these mass transportation experts for the use of their capabilities in time of emergency. Transportation which might be relegated to the activity zone includes private cars and smaller trucks (including moving vans). Possible sources of transportation which could be inventoried are moving companies, truck and car rental agencies, new and used car dealers (a secondary choice since such cars are normally filled with only a nominal amount of fuel) and parking garages. A final source of transportation, though one which cannot be precisely inventoried, is privately owned automobiles. The statistical availability of privately owned cars can be determined from license registrations for the community or by assigning a fraction of a car to each household, but no assurance is given as to the location of vehicles at time of attack. (If cars are driven to shelters, as proposed in many communities, a surfeit of cars around the shelter can be assumed.)

Fuel supplies for vehicles (service stations primarily), can be determined as a part of the general resource inventory (see below) but such supplies should not be relied upon unless auxiliary pumps to remove the fuel from underground storage are available. (In case of power failure, service station pumps are inoperable.)

Heavy equipment, which could be used for applied shielding or to clear debris from roads, is, because of its importance to the civil defense organization, being inventoried by the Association of General Contractors under Operation Bulldozer (Ref. 32). The Department of the Army (Ref. 33) also inventories construction equipment, but this information has the disadvantage of being only periodic. However, at best, any inventory of construction equipment can only supply information on the availability of equipment within a general area, but not its specific location, a consequence of the mobility of such equipment and its frequent use at widely separated sites. For local use within the activity zone, small equipment, such as fork lift trucks and front-end loaders, which may be invaluable in supporting peripheral countermeasures, may be used regularly in warehouses, manufacturing plants, etc., and thus can be inventoried as an available resource. Information on the availability of small in-house equipment is normally not available, and inventorying might require the cooperation of the owners and/or operators.

An inventory of miscellaneous resources, such as food, clothing, drugs, fuel, etc., needed in support of peripheral countermeasures can be made for a community using a number of sources. Such an inventory must be inclusive, not selective, and must provide information on location, type of resource, and approximate quantity of the resource. Headquarters of large companies, trade associations, etc., are usually not desirable because of their narrow range of interests. Instead, informational sources which cover a broad spectrum and blanket the entire community are desired. One such source is the telephone directory, using either the yellow pages which categorize according to product, or a street-by-street listing of telephone subscribers (this latter special

service may not be offered in all municipalities). The street-by-street listing is probably the more useful, but has limitations in that the individual listing may not identify the product and will not provide any index of the size of the supplier. A further limitation on the use of telephone listings is the fact that stores may not be listed as such, but under a family name or under a corporate heading (frequently done by chain stores).

City directories, published for most of the larger communities in the nation, offer a more comprehensive, yet regularly revised, source of information. These directories, used by businessmen, direct mail advertisers, etc., typically include both a classified listing and a street-by-street listing which includes the type of business. By using such a directory, the type and location of a number of resources can quickly be ascertained, although no index as to size is included. However, once a resource is categorized, well-informed persons can usually make a fair estimate of its capacity or size. A more sophisticated, albeit expensive, approach to a resource inventory is the use of the categorized mailing lists, available from the publishers of city directories, for any community, even those not boasting a city directory. These lists, normally restricted only as to category (e.g., bakery) and community, can also include size of the business and block location. For example, R.L. Polk,<sup>1</sup> the largest of the city directory publishers, will supply a street-by-street index of all retail grocers, annotated as to gross worth (small, medium, or large), at a cost of \$150.00 per 1000 names. The use of such a service would provide an inventory of community resources quickly and at relatively low cost.

However, the municipality may have informational sources of its own which the civil defense organization would prefer to use. Business licenses, if files are current and categorized as to type and/or location, could furnish the necessary information. A particularly good source of detailed information is the fire department and/or fire marshal inspection files. Fire departments normally inspect commercial buildings at least

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<sup>1</sup> R. L. Polk & Co., Direct Mail Division, 431 Howard Street, Detroit, Michigan 48231

once a year, noting, among other things, the type of occupancy, the area occupied, and fire hydrant connections (useful for planning decontamination operation). The files, usually indexed on a block-by-block basis, may be stored at local firehouses or in a central file.

Fire department files have been found to afford some of the best information available, are readily accessible, and are current. Some police departments maintain similar, but not such extensive files; however, these files may, because of their sensitive nature, not be available for civil defense use.

Vital facilities or important resources would be so designated on the basis of requirements for services or resources, by higher echelons, i.e., municipal, county, or state. A partial list of such facilities would include: critical elements of utilities (electric-power plants, substations, water-treatment plants, emergency pumps, etc.), basic industries (oil refineries, steel mills, etc.), high-value perishable goods (frozen-food storage, meat plants, etc.), and wholesale distributors (grocers, hardware, drugs, etc.). Such facilities would receive support from the shelter within the activity zone, but the shelter would not exercise control over these facilities. The data from a resource inventory, in order to be of value, must be presented in a logical form and distributed to interested persons. A master list for the entire community of all resources in block-by-block or street-by-street order should be retained at the EOC. Inventory lists for each activity zone should be prepared and placed in each shelter. Addendums to and deletions from the inventory list should be issued periodically. And finally, shelter managers must become acquainted with these inventory lists and the concepts of preattack planning as a necessary prelude to postattack implementation.

## Appendix G

## IN SITU ASSESSMENT OF RADIOLOGICAL PROTECTION OF SHELTER STRUCTURES

For preattack planning it is convenient to use semiempirical models, such as Ref. 15, which assume a uniform infinite fallout deposit, to estimate the PF as an index of the protection which a shelter might afford. However, in an actual situation, this index may be modified by several factors, the most important being (1) the nonuniformity of the fallout deposit, (2) surface roughness effects, (3) ingress of fallout into the shelter structure, (4) shielding provided by the contents of the shelter structure (e.g., desks, stocks, equipment, etc.), (5) mutual shielding effects created by the spatial distribution of people in the shelter area.<sup>1</sup>

Since many of these parameters are unpredictable and all can vary greatly in real situations, it is a difficult, if not impossible, task to assess possible effects on the protection afforded by the shelter. Consequently, the radiological situation in a shelter must be determined by postattack monitoring and the information then used to delineate radiological hazards. All areas within the designated shelter should be monitored, and any area having excessive dose rates should be excluded from further use or else appropriate peripheral countermeasures (such as applied shielding or shelter rotation) should be instituted. In addition, other areas of the building should be monitored in order to determine the existence of other potential shelter areas. In multistory buildings, the area selected initially for the shelter may not provide the lowest dose rate. For example, the 7th floor of an office building might, by calculation, be the choice for a shelter, but an in situ survey might prove that the 5th, 6th, or even the 8th floor would afford better protection. If an excess of low dose rate spaces are found within the shelter building, those with the lowest dose rate (and meeting other criteria for use as a shelter) would be used.

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<sup>1</sup> The influence of other buildings in the general area is incorporated in the preattack computation. However, the stylized assumptions inherent in the computation of this influence (as well as other limitations in the computational procedure) may also result in significant deviations from the predicted protection values.

A suggested procedure for an in situ assessment of the protection of shelter areas in tall buildings is as follows:

1. The designated shelter area is occupied initially and dose rate values are obtained throughout this area. For comparative purposes mutual shielding effects can be largely eliminated by moving shelterees away from the detector as readings are taken. These data would serve as a base for comparison with other potential shelter areas in the structure.
2. Survey each of the two stories above and the two stories below the shelter area, measuring the dose rate in all areas that might be occupied. Also make a visual check for broken windows and possible ingress of fallout into the shelter structure.
  - a. If the results of the survey approximate curve A in Fig. G-1, the optimum story was preselected and there is no advantage, from a radiation standpoint, in moving to another floor.
  - b. If a curve similar to B is found, it can be surmised (as a first estimate) that roof contribution is dominating or ingress of fallout into upper floors has occurred. The possibility of moving to a lower floor or undertaking other corrective action should be considered.
  - c. If the plotted curve resembles C, it is probable that dose rate from the ground or adjoining roofs is greater than that from the roof and an advantage would result from moving to a higher floor.
3. A plot of the radiation readings across a designated or potential shelter area can provide useful information as to the possible source(s) of the radiation. Figure G-2 (from Ref. 34) gives an example of the theoretical variation in dose rate in a simple above-ground shelter. Curve A is typical for a shelter in which all radiation is received from the roof. Curve B is typical of a shelter in which roof and ground contributions at the center are approximately equal. Curve C is typical for a shelter in which all radiation is received from the ground. If the source of the radiation is known with some certainty, appropriate corrective action can be undertaken to reduce the dose rate within the shelter. For example, in the case typified by Curve A, effort would be directed at reducing the roof contribution and would not be needlessly expended elsewhere.

The procedure outlined above is not intended to be either comprehensive or quantitative, but is an attempt to suggest an area for further research. Basement shelters may also be amenable to an in situ radiological assessment, although more sophisticated techniques might be required.



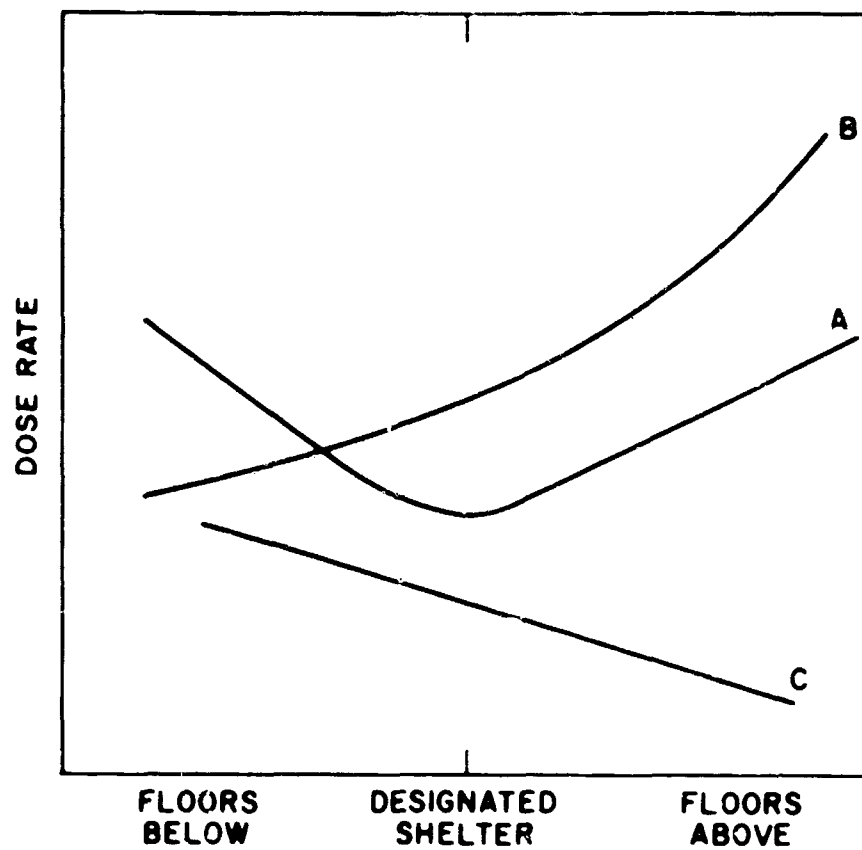


Fig. G-1. Typical Variation of Dose Rate at Various Heights in a Tall Building

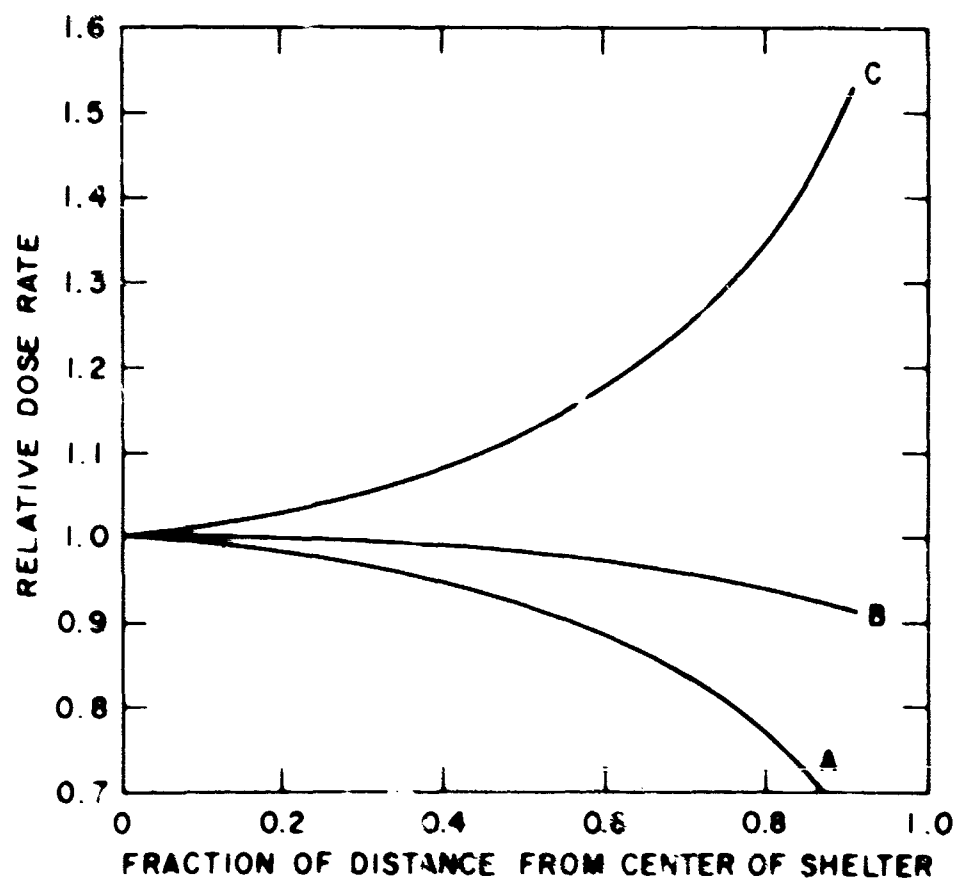


Fig. G-2. Variation of Relative Dose Rate With Detector Location and Radiation Source

The consideration of the RSA (reduced space allocation) concept to increase the number of shelter spaces available, creates a further justification for seeking out and evaluating unidentified shelter spaces. For example, if a designated shelter were filled to 150 percent of rated capacity, it would be desirable to transfer a portion of the shelter population to other protected areas within the shelter structure. Such spaces might not be readily identifiable in a preattack analysis of the building, but would be readily located by a postattack survey.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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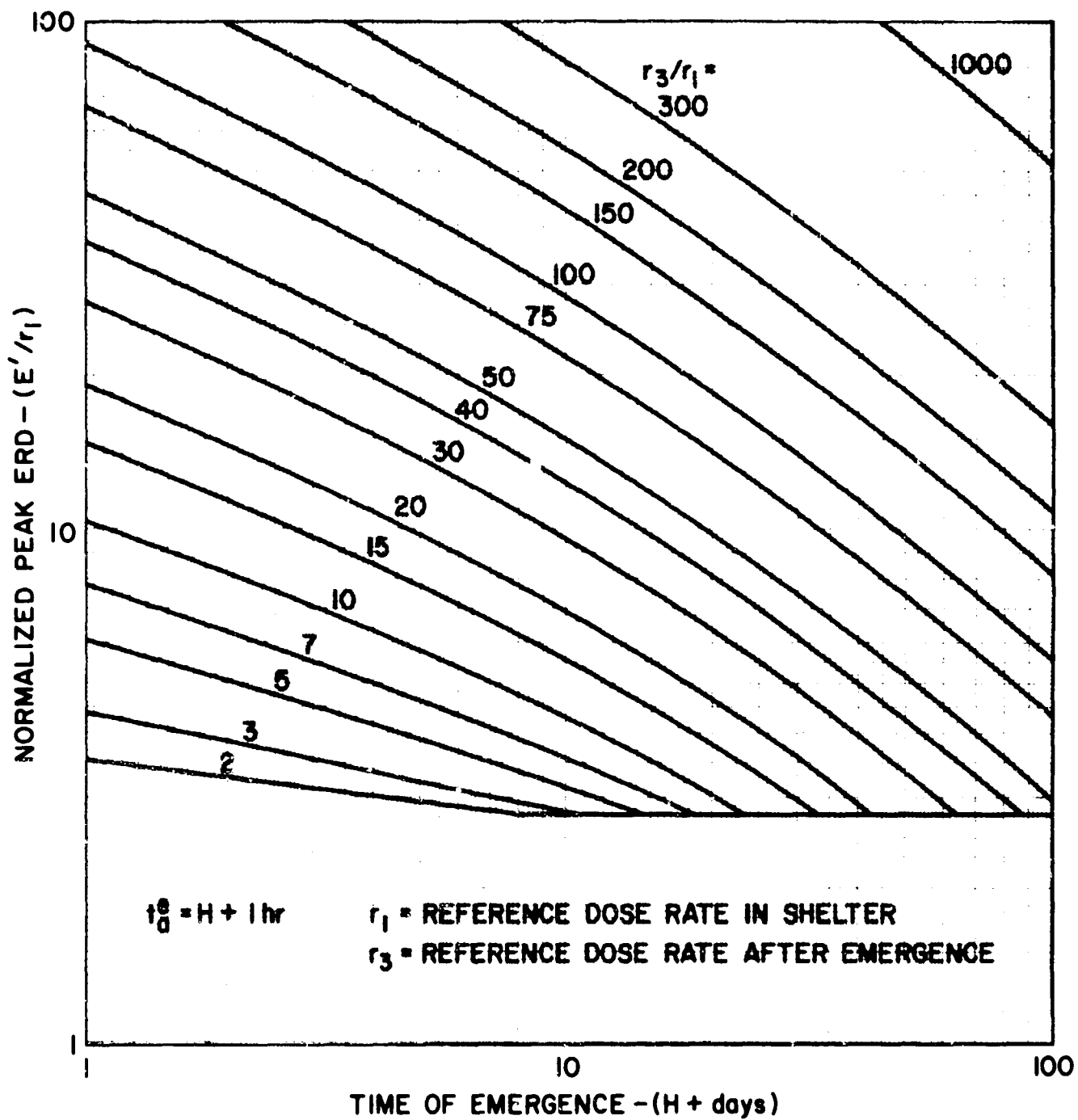


Fig. B-3. Peak ERD vs Time of Emergence for Two-Stage Movement and Effective Time of Arrival of 1 hr

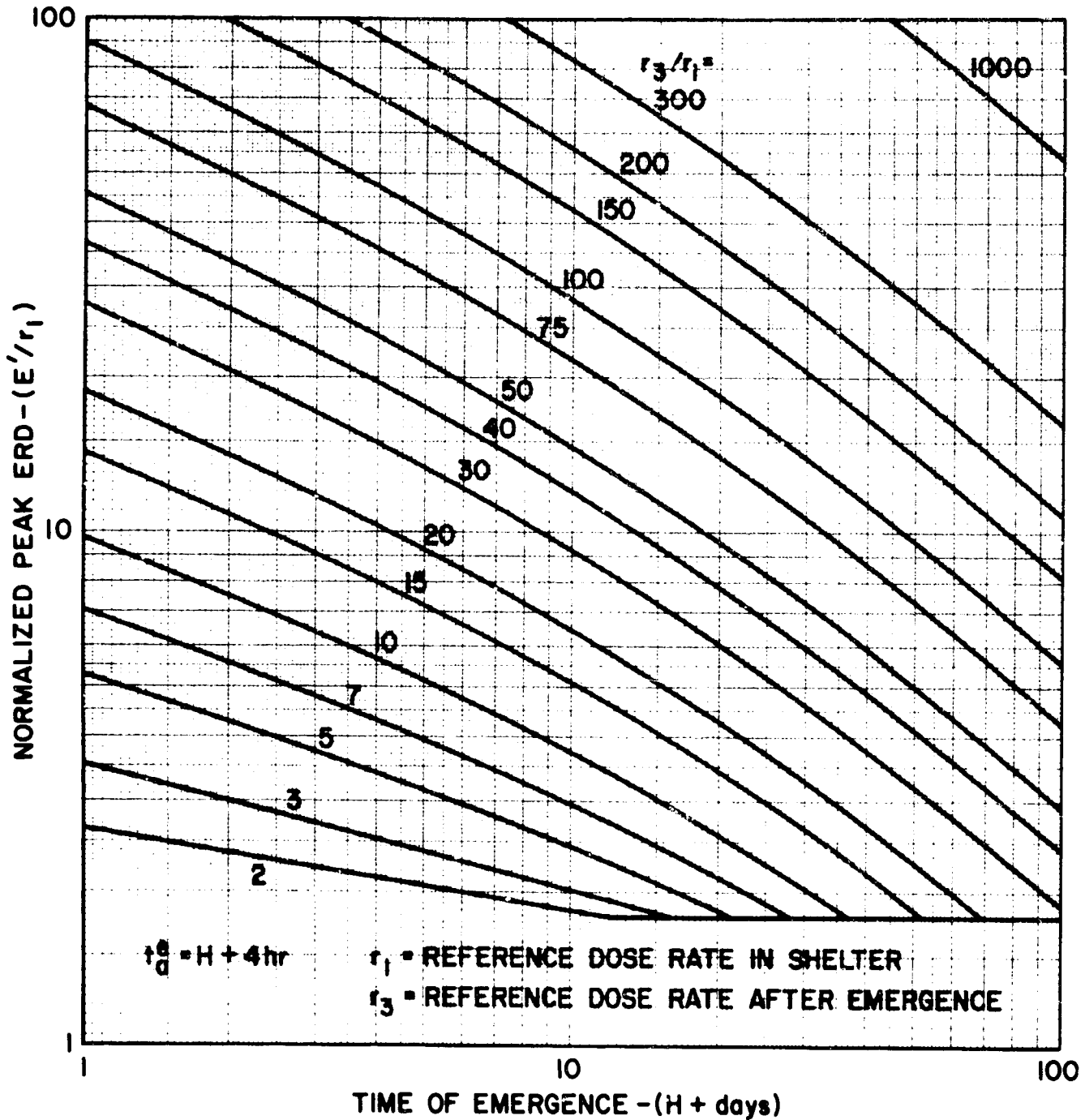


Fig. B-4. Peak ERD vs Time of Emergence for Two-Stage Movement and Effective Time of Arrival of 4 hr

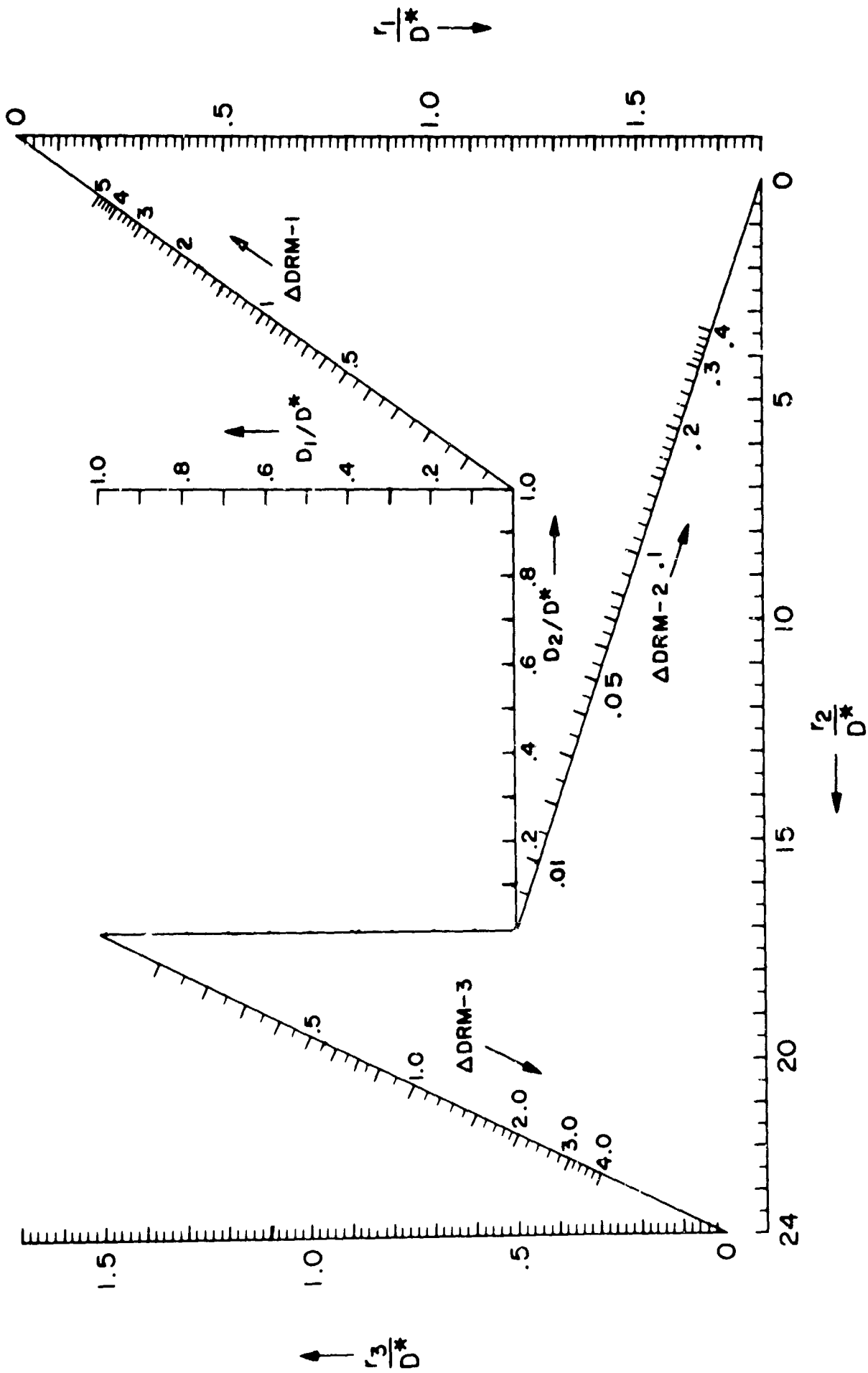


Fig. B-8. Nomograph of Relationship of Dose Received in Three Radiological Environments

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